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- 1 -

Michael Moores

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CHEMICALLY-DEFINED NON-POLYMERIC VALENCY
PLATFORM MOLECULES AND CONJUGATES THEREOF

Cross-Reference to Related Applications

This application is a continuation-in-part
10 (CIP) of U.S. Serial No. 07/914,869, filed 15 July 1992,
which is a CIP of U.S. Serial No. 07/494,118, filed 13
March 1990, now U.S. Patent No. 5,162,515, issued 10
November 1992, which in turn is a CIP of U.S. Serial No.
466,138, filed 16 January 1990, now abandoned, and, in
15 addition, a continuation-in-part of U.S. Serial No.
08/118,055, filed 8 September 1993, which is a CIP of
U.S. Serial No. 07/652,648, filed 8 February 1991. The
disclosure of each of these parent applications is
incorporated herein by reference.

20

Description

Technical Field

This invention relates to conjugates comprising
25 chemically-defined, non-polymeric valency platform
molecules coupled to biological or chemical molecules
such as polynucleotides for treating diseases such as the
autoimmune disease systemic lupus erythematosus (SLE or
"lupus"). This invention also relates to the chemically-
30 defined, non-polymeric valency platform molecules.

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-2-

Background

5 A number of compounds have been employed as carriers for biologically useful molecules in preparing conjugates that are alleged to be tolerogenic. For example, Benacerraf, Katz, and their colleagues investigated and described the use of conjugates of the random co-polymer D-glutamic acid/D-lysine, referred to as D-GL in earlier literature (hereinafter D-EK) with haptens and various antigens to induce specific immune tolerance. See U.S. Pats. Nos. 4,191,668 and 4,220,565.

10 Other investigators have studied conjugates of nucleosides or DNA with other carriers. Borel et al. (Science (1973) 182:76) evaluated the ability of isogenic mouse IgG-nucleoside conjugates to reduce the antibody response to denatured DNA in young animals of the NZB mouse strain. In separate studies Parker et al. (J. Immunol. (1974) 113:292) evaluated the effect of denatured DNA conjugated to poly-D-lysine and/or cyclophosphamide on the progression of the above-described syndrome in NZB mice.

20 In a later article (Ann NY Acad Sci (1986) 475:296-306) Borel et al. describe oligonucleotide-immunoglobulin conjugates. Borel et al. (J Clin Invest (1988) 82:1901-1907 or U.S. 4,650,675) have described in vitro studies using conjugates of human immunoglobulin linked to DNA. U.S. Patent No. 5,126,131 (Dintzis et al.) also relates to conjugates comprising carriers and molecules involved in immune responses.

30 Other references describe conjugates of nonimmunogenic polymers and immunogens (Saski et al., Scand. J. Immun. (1982) 16:191-200; Sehon, Prog. Allergy (1982) 32:161-202; Wilkinson et al., J. Immunol. (1987)

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-3-

139:326-331, and Borel et al., J. Immunol. Methods (1990)
126:159-168).

5 In commonly-owned U.S. Serial Nos. 07/914,869,
U.S. Patent No. 5,162,515, and 07/652,658, conjugates
comprising polymeric carriers such as D-EK, polyethylene
glycol, poly-D-lysine, polyvinyl alcohol, polyvinyl
pyrrolidone and immunoglobulins are described.

10 In sum, applicants believe that the prior art
shows only ill-defined chemical compounds or compounds
with numerous non-specific attachment sites employed as
valency platform molecules in conjugates. Because the
valency of such compounds, the specific location of the
15 attachment sites, and the number of attachment sites are
unpredictable and fluctuates widely, prior art conjugates
comprising such compounds cannot be made reproducibly and
show wide ranges in their reported activity.

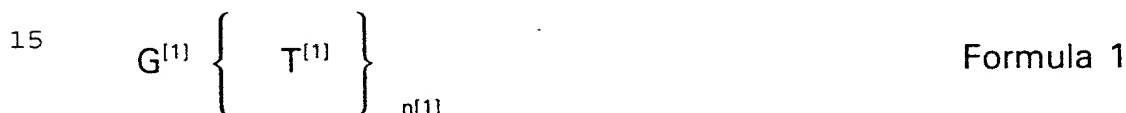
Disclosure of the Invention

20 In contrast to the above-described art,
applicants have developed conjugates comprising
chemically-defined, non-polymeric valency platform
molecules wherein the valency of the platform molecules
is predetermined and wherein each attachment site is
25 available for binding of a biological or chemical
molecule. Valency platform molecules within the present
invention are defined with respect to their chemical
structure, valency, homogeneity and a defined chemistry
which is amenable to effective conjugation with the
30 appropriate biological and/or chemical molecules.

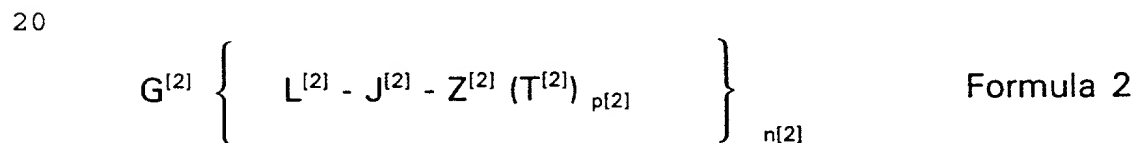
35 Thus, one aspect of the instant invention is
directed to conjugates comprising the chemically-defined,
non-polymeric valency platform molecules and biological
and/or chemical molecules. Exemplary of biological

-4-

and/or chemical molecules suitable for conjugation to
chemically-defined, non-polymeric valency platform
molecules to form conjugates within the instant invention
are carbohydrates, drugs, lipids, lipopolysaccharides,
peptides, proteins, glycoproteins, single-stranded or
double-stranded oligonucleotides and chemical analogs
thereof, analogs of immunogens, haptens, mimotopes,
aptamers and the like. Chemically-defined, non-polymeric
valency platform molecules suitable for use within the
present invention include, but are not limited to,
derivatives of biologically compatible and nonimmunogenic
carbon-based compounds of the following formulae:



or



wherein

each of $G^{[1]}$ and $G^{[2]}$, if present, is independently a
linear, branched or multiply-branched chain comprising 1-
2000, more preferably 1-1000, chain atoms selected from
the group C, N, O, Si, P and S;

more preferably, $G^{[2]}$, if present, is a radical
derived from a polyalcohol, a polyamine, or a polyglycol;
most preferably, $G^{[2]}$ is selected from the group $-(CH_2)_q-$
wherein $q=0$ to 20, $-CH_2(CH_2OCH_2)_rCH_2-$, wherein $r=0$ to 300,

-5-

and $C(CH_2OCH_2CH_2-)_s(OH)_{4-s}$ wherein $s=1$ to 4 , more preferably $s=3$ to 4 ;

each of the $n^{[1]}$ moieties shown as $T^{[1]}$ and each of the $p^{[2]} \times n^{[2]}$ moieties shown as $T^{[2]}$ is independently chosen from the group

NHR^{SUB} (amine), $C(=O)NHNHR^{SUB}$ (hydrazide), $NHNHR^{SUB}$ (hydrazine), $C(=O)OH$ (carboxylic acid), $C(=O)OR^{ESTER}$ (activated ester), $C(=O)OC(=O)R^B$ (anhydride), $C(=O)X$ (acid halide), $S(=O)_2X$ (sulfonyl halide), $C(=NR^{SUB})OR^{SUB}$ (imide ester), NCO (isocyanate), NCS (isothiocyanate), $OC(=O)X$ (haloformate), $C(=O)OC(=NR^{SUB})NHR^{SUB}$ (carbodiimide adduct), $C(=O)H$ (aldehyde), $C(=O)R^B$ (ketone), SH (sulfhydryl or thiol), OH (alcohol), $C(=O)CH_2X$ (haloacetyl), $R^{ALK}X$ (alkyl halide), $S(=O)_2OR^{ALK}X$ (alkyl sulfonate), NR^1R^2 wherein R^1R^2 is $-C(=O)CH=CHC(=O)-$ (maleimide), $C(=O)CR^B=CR^B_2$ (α, β -unsaturated carbonyl), $R^{ALK}-Hg-X$ (alkyl mercurial), and $S(=O)CR^B=CR^B_2$ (α, β -unsaturated sulfone);

more preferably each of the $n^{[1]}$ moieties shown as $T^{[1]}$ and each of the $p^{[2]} \times n^{[2]}$ moieties shown as $T^{[2]}$ is independently chosen from the group NHR^{SUB} (amine), $C(=O)CH_2X$ (haloacetyl), $R^{ALK}X$ (alkyl halide), $S(=O)_2OR^{ALK}X$ (alkyl sulfonate), NR^1R^2 wherein R^1R^2 is $-C(=O)CHCHC(=O)-$ (maleimide), $C(=O)CR^B=CR^B_2$ (α, β -unsaturated carbonyl), $R^{ALK}-Hg-X$ (alkyl mercurial), and $S(=O)CR^B=CR^B_2$ (α, β -unsaturated sulfone);

even more preferably each of the $n^{[1]}$ moieties shown as $T^{[1]}$ and each of the $p^{[2]} \times n^{[2]}$ moieties shown as $T^{[2]}$ is independently chosen from the group NHR^{SUB} (amine), $C(=O)CH_2X$ (haloacetyl), NR^1R^2 wherein R^1R^2 is $-C(=O)CHCHC(=O)-$ (maleimide), and $C(=O)CR^B=CR^B_2$ (α, β -unsaturated carbonyl);

-6-

most preferably, all of the $n^{[1]}$ moieties shown as $T^{[1]}$ and all of the $p^{[2]} \times n^{[2]}$ moieties shown as $T^{[2]}$ are identical;

5 wherein

each X is independently a halogen of atomic number greater than 16 and less than 54 or other good leaving group (i.e., weak bases such as alkyl or alkyl-substituted sulfonates or sulfates and the like, aryl or aryl-substituted sulfonates or sulfates and the like that act similarly to a halogen in this setting);

each R^{ALK} is independently a linear, branched, or cyclic alkyl (1-20C) group;

each R^{SUB} is independently H, linear, branched, or cyclic alkyl (1-20C), aryl (6-20C), or alkaryl (7-30C);

each R^{ESTER} is independently N-succinimidyl, p-nitrophenyl, pentafluorophenyl, tetrafluorophenyl, pentachlorophenyl, 2,4,5-trichlorophenyl, 2,4-dinitrophenyl, cyanomethyl and the like, or other activating group such as 5-chloro,8-quinolone, 1-piperidine, N-benzotriazole and the like;

each R^B is independently a radical comprising 1-50 atoms selected from the group C, H, N, O, Si, P and S;

each of the $n^{[2]}$ moieties shown as $L^{[2]}$, if present, is independently chosen from the group O, NR^{SUB} and S;

each of the $n^{[2]}$ moieties shown as $J^{[2]}$, if present, is independently chosen from the group $C(=O)$ and $C(=S)$;

$n^{[1]} = 1$ to 32, more preferably $n^{[1]} = 2$ to 16, even more preferably $n^{[1]} = 2$ to 8, most preferably $n^{[1]} = 2$ to 4;

$n^{[2]} = 1$ to 32, more preferably $n^{[2]} = 1$ to 16, even more preferably $n^{[2]} = 1$ to 8, yet more preferably $n^{[2]} = 1$ to 4, most preferably $n^{[2]} = 1$ to 2;

-7-

$p^{[2]} = 1$ to 8, more preferably $p^{[2]} = 1$ to 4, most preferably $p^{[2]} = 1$ to 2;

with the proviso that the product $n^{[2]} \times p^{[2]}$ be greater than 1 and less than 33;

each of the $n^{[2]}$ moieties shown as $Z^{[2]}$ is independently a radical comprising 1-200 atoms selected from the group C, H, N, O, Si, P and S, containing attachment sites for at least $p^{[2]}$ functional groups on alkyl, alkenyl, or aromatic carbon atoms;

more preferably, all of the $n^{[2]}$ moieties shown as $Z^{[2]}$ are identical;

more preferably, each of the $n^{[2]}$ moieties shown as $Z^{[2]}$ is independently described by a formula chosen from the group:

$Z^{[2]}$ is $W^{[3]} - Y^{[3]} (\text{attachment site})_{p^{[2]}}$ Formula 3

$Z^{[2]}$ is $W^{[4]} - N \left\{ Y^{[4]} (\text{attachment site})_{p^{[2]}/2} \right\}_2$ Formula 4

$Z^{[2]}$ is $W^{[5]} - CH \left\{ Y^{[5]} (\text{attachment site})_{p^{[2]}/2} \right\}_2$ Formula 5

wherein

each of the $n^{[2]}$ moieties shown as $W^{[3]}$, $W^{[4]}$, or $W^{[5]}$, if present, is independently a radical comprising 1-100 atoms selected from the group C, H, N, O, Si, P and S;

each of the $n^{[2]}$ moieties shown as $Y^{[3]}$, each of the $2 \times n^{[2]}$ moieties shown as $Y^{[4]}$, and each of the $2 \times n^{[2]}$ moieties shown as $Y^{[5]}$ is independently a radical comprising 1-100 atoms selected from the group C, H, N, O, Si, P and S, containing attachment sites for at least

-8-

$p^{[2]}$ (for $Y^{[3]}$) or $p^{[2]}/2$ (for $Y^{[4]}$ and $Y^{[5]}$, where $p^{[2]}/2$ is an integer) functional groups on alkyl, alkenyl, or aromatic carbon atoms;

5 more preferably, each of the $n^{[2]}$ moieties shown as $W^{[3]}$, if present, is independently chosen from the group $(CH_2)_r$, $(CH_2CH_2O)_r$, $NR^{SUB}(CH_2CH_2O)_rCH_2CH_2$, and $NR^{SUB}(CH_2)_rNR^{SUB}C(=O)$, wherein $r=1$ to 10;

10 more preferably, each of the $n^{[2]}$ moieties shown as $Y^{[3]}$ is independently linear, branched, or cyclic alkyl (1-20C), aryl (6-20C), or alkaryl (7-30C); most preferably, each of the $n^{[2]}$ moieties shown as $Y^{[3]}$ is independently chosen from the group C_6H_4 (phenyl-1,4-diradical), C_6H_3 (phenyl-1,3,5-triradical), and $(CH_2)_r$ wherein $r=1$ to 10;

15 more preferably, each of the $n^{[2]}$ moieties shown as $W^{[4]}$, if present, is independently chosen from the group $(CH_2)_rC(=O)$ and $(CH_2)_rNR^{SUB}C(=O)$, wherein $r=1$ to 10;

20 more preferably, each of the $2 \times n^{[2]}$ moieties shown as $Y^{[4]}$, is independently chosen from the group $(CH_2)_r$, $(CH_2)_rNR^{SUB}C(=O)(CH_2)_q$, $(CH_2)_rC(=O)NR^{SUB}(CH_2)_q$, $(CH_2)_rNR^{SUB}C(=O)(CH_2)_qNR^{SUB}C(=O)(CH_2)_r$, $(CH_2)_rC(=O)NR^{SUB}(CH_2)_qNR^{SUB}C(=O)(CH_2)_r$, $(CH_2)_rNR^{SUB}C(=O)(CH_2CH_2O)_qCH_2CH_2$, and $(CH_2)_rC(=O)NR^{SUB}(CH_2CH_2O)_qCH_2CH_2$, wherein $r=1$ to 10, more preferably $r=2$ to 6, and $q=1$ to 10, more preferably $q=1$ to 3;

25 more preferably, each of the $n^{[2]}$ moieties shown as $W^{[5]}$, if present, is independently chosen from the group $(CH_2)_rC(=O)NR^{SUB}$ and $(CH_2)_rNR^{SUB}C(=O)NR^{SUB}$, wherein $r=1$ to 10;

30 more preferably, each of the $2 \times n^{[2]}$ moieties shown as $Y^{[5]}$, is independently chosen from the group $(CH_2)_r$ and $(CH_2)_rC(=O)NR^{SUB}(CH_2)_q$, wherein $r=1$ to 10 and $q=1$ to 10.

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-9-

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In a further preferred embodiment for treating lupus, a conjugate comprises a chemically-defined, non-polymeric valency platform molecule and a multiplicity of polynucleotide duplexes of at least about 20 base pairs each bound to the platform molecule, and having significant binding activity for human SLE anti-dsDNA autoantibodies. In these preferred embodiments, the polynucleotide duplexes are substantially homogeneous in length and one strand of the duplex is conjugated to the valency platform molecule either directly or via a linker molecule. Usually synthetic polynucleotides are coupled to a linker molecule before being coupled to a valency platform molecule. Usually the linker containing strand of the duplex is coupled at or proximate (i.e. within about 5 base pairs) one of its ends such that each strand forms a pendant chain of at least about 20 base pairs measured from the site of attachment of the strand to the linker molecule. The second strand is then annealed to the first strand to form a duplex. Thus, a conjugate within the present invention can be generally described by the following formula:

$$[(PN)_n\text{-linker}]_m\text{-valency platform molecule.}$$

wherein PN = a double stranded polynucleotide with "n" nucleotides, wherein n = at least about 20, and m = 2-8.

Exemplary of suitable linker molecules within the present invention are 6 carbon thiols such as HAD, a thio-6 carbon chain phosphate, and HAD_pS, a thio-6 carbon chain phosphorothioate. Chemically-defined valency platform molecules within the present invention are formed, for example, by reacting amino modified-PEG with 3,5-bis-(iodoacetamido) benzoyl chloride (hereinafter

-10-

"DABA"); 3-carboxypropionamide-N,N-bis-[(6'-N'-
carbobenzyloxyaminohexyl)acetamide] 4"-nitrophenyl ester
(hereinafter "BAHA"); 3-carboxypropionamide-N,N-bis-[(8'-
N'-carbobenzyloxyamino-3',6'-dioxaoctyl)acetamide] 4"-
5 nitrophenyl ester (hereinafter "BAHA_{ox}"); or by reacting
PEG-bis-chloroformate with N,N-di(2-[6'-N'-
carbobenzyloxyaminohexanoamido]ethyl)amine (hereinafter
"AHAB") to form chemically-defined valency platform
10 molecules.

Surprisingly unexpected results of at least
approximately ten fold up to more than one-hundred fold
increase in immunosuppression are achieved using
conjugates comprising the chemically-defined, non-
15 polymeric valency platform molecules of the instant
invention and biological or chemical molecules (non-
haptens) when compared to the polymeric carriers
described in the prior art. For example, at least a one
hundred-fold increase in the immunosuppression of anti-
20 dsDNA autoantibodies was achieved as described herein
using conjugates within the present invention comprising
chemically-defined, non-polymeric valency platform
molecules when compared to conjugates comprising an ill-
defined carrier described in the prior art.

25 Still another aspect is a conjugate of (a) a
chemically-defined, non-polymeric valency platform
molecule and (b) a multiplicity of polynucleotide
duplexes each and all of which is bound to the valency
platform molecule by a functional group located at or
30 proximate a terminus of one of the strands of the duplex,
said conjugate being a human SLE tolerogen.

Pharmaceutical compositions of the above-described
conjugates and pharmaceutically acceptable vehicles are
35 another aspect of the invention.

-11-

A further aspect of the invention is a method for treating SLE in an individual in need of such treatment comprising administering to the individual an effective amount of the above-described conjugates.

Yet another aspect of the invention is a method of inducing specific B cell anergy to an immunogen in an individual comprising administering to the individual an effective amount of the above-described conjugates.

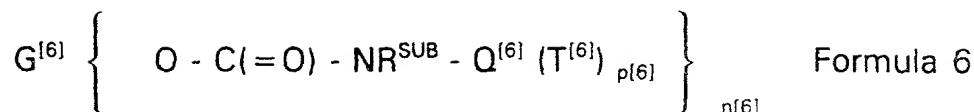
Another aspect of the invention is a method of treating an individual for an antibody-mediated pathology in which undesired antibodies are produced in response to an immunogen comprising administering to the individual an effective amount of the above-described conjugates.

A further aspect of the invention is a method for making the conjugates described above comprising: covalently bonding the biological or chemical molecule to a chemically-defined valency platform molecule to form a conjugate.

A further aspect of the invention is a method for making the conjugates for treating SLE described above comprising: reacting a multiplicity of single-stranded polynucleotides each of which is at least about 20 nucleotides in length and has a functional group at or proximate one of its termini that reacts with functional groups on the chemically-defined valency platform molecule to form a conjugate, and annealing complementary single-stranded polynucleotides to the single-stranded polynucleotides conjugated to the chemically-defined valency platform molecule to form pendant chains of double-stranded DNA.

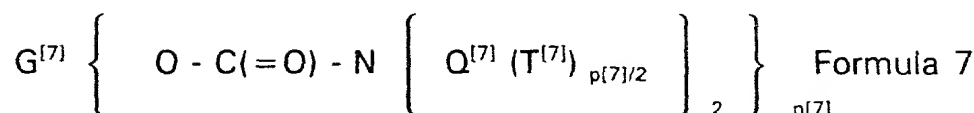
Yet another aspect of the invention is directed to novel chemically-defined, non-polymeric valency platform molecules of the formulae:

-12-



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or



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wherein

each of $G^{[6]}$ and $G^{[7]}$, if present, is independently a linear, branched or multiply-branched chain comprising 1-2000, more preferably 1-1000, chain atoms selected from the group C, N, O, Si, P and S; more preferably, each of $G^{[6]}$ and $G^{[7]}$ is a radical derived from a polyalcohol, a polyamine, or a polyglycol; most preferably, each of $G^{[6]}$ and $G^{[7]}$ is selected from the group $-(CH_2)_q-$ wherein $q=0$ to 20, $-CH_2(CH_2OCH_2)_rCH_2-$, wherein $r=0$ to 300, and $C(CH_2OCH_2CH_2)_s(OH)_{4-s}$ wherein $s=1$ to 4, more preferably $s=3$ to 4;

each of the $n^{[6]} \times p^{[6]}$ moieties shown as $T^{[6]}$ and each of the $n^{[7]} \times p^{[7]}$ moieties shown as $T^{[7]}$ is independently chosen from the group

25 NHR^{SUB} (amine), $C(=O)NHNHR^{SUB}$ (hydrazide), $NHNHR^{SUB}$ (hydrazine), $C(=O)OH$ (carboxylic acid), $C(=O)OR^{ESTER}$ (activated ester), $C(=O)OC(=O)R^B$ (anhydride), $C(=O)X$ (acid halide), $S(=O)_2X$ (sulfonyl halide), $C(=NR^{SUB})OR^{SUB}$ (imide ester), NCO (isocyanate), NCS (isothiocyanate),

30 $OC(=O)X$ (haloformate), $C(=O)OC(=NR^{SUB})NHR^{SUB}$ (carbodiimide adduct), $C(=O)H$ (aldehyde), $C(=O)R^B$ (ketone), SH (sulfhydryl or thiol), OH (alcohol), $C(=O)CH_2X$ (haloacetyl), $R^{ALK}X$ (alkyl halide), $S(=O)_2OR^{ALK}$ (alkyl sulfonate), NR^1R^2 wherein R^1R^2 is $-C(=O)CHCHC(=O)-$

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-13-

(maleimide), $C(=O)CR^B=CR^B_2$ (α,β -unsaturated carbonyl), $R^{ALK}-Hg-X$ (alkyl mercurial), and $S(=O)CR^B=CR^B_2$ (α,β -unsaturated sulfone);

5 more preferably, each of the $n^{[6]} \times p^{[6]}$ moieties shown as $T^{[6]}$ and each of the $n^{[7]} \times p^{[7]}$ moieties shown as $T^{[7]}$ is independently chosen from the group NHR^{SUB} (amine), $C(=O)CH_2X$ (haloacetyl), $R^{ALK}X$ (alkyl halide), $S(=O)_2OR^{ALK}X$ (alkyl sulfonate), NR^1R^2 wherein R^1R^2 is $-C(=O)CHCHC(=O)-$ (maleimide), $C(=O)CR^B=CR^B_2$ (α,β -unsaturated carbonyl), $R^{ALK}-Hg-X$ (alkyl mercurial), and $S(=O)CR^B=CR^B_2$ (α,β -unsaturated sulfone);

even more preferably each of the $n^{[6]} \times p^{[6]}$ moieties shown as $T^{[6]}$ and each of the $n^{[7]} \times p^{[7]}$ moieties shown as $T^{[7]}$ is independently chosen from the group NHR^{SUB} (amine), $C(=O)CH_2X$ (haloacetyl), NR^1R^2 wherein R^1R^2 is $-C(=O)CH=CHC(=O)-$ (maleimide), and $C(=O)CR^B=CR^B_2$ (α,β -unsaturated carbonyl);

15 most preferably, all of the $n^{[6]} \times p^{[6]}$ moieties shown as $T^{[6]}$ and all of the $n^{[7]} \times p^{[7]}$ moieties shown as $T^{[7]}$ are identical;

wherein

each X is independently a halogen of atomic number greater than 16 and less than 54 or other good leaving group;

25 each R^{ALK} is independently a linear, branched, or cyclic alkyl (1-20C) group;

each R^{SUB} is independently H, linear, branched, or cyclic alkyl (1-20C), aryl (1-20C), or alkaryl (1-30C);

30 each R^{ESTER} is independently N-hydroxysuccinimidyl, p-nitrophenoxy, pentafluorophenoxy, or other activating group;

35 each R^B is independently a radical comprising 1-50 atoms selected from the group C, H, N, O, Si, P and S;

-14-

$n^{[6]} = 1$ to 32, more preferably $n^{[6]} = 1$ to 16, even more preferably $n^{[6]} = 1$ to 8, yet more preferably $n^{[6]} = 1$ to 4, most preferably $n^{[6]} = 1$ to 2;

5 $p^{[6]} = 1$ to 8, more preferably $p^{[6]} = 1$ to 4, most preferably $p^{[6]} = 1$ to 2;

with the proviso that the product $n^{[6]} \times p^{[6]}$ be greater than 1 and less than 33;

10 $n^{[7]} = 1$ to 32, more preferably $n^{[7]} = 1$ to 16, even more preferably $n^{[7]} = 1$ to 8, yet more preferably $n^{[7]} = 1$ to 4, most preferably $n^{[7]} = 1$ to 2;

$p^{[7]} = 1$ to 8, more preferably $p^{[7]} = 1$ to 4, most preferably $p^{[7]} = 1$ to 2;

15 with the proviso that the product $n^{[7]} \times p^{[7]}$ be greater than 1 and less than 33;

each of the $n^{[6]}$ moieties shown as $Q^{[6]}$ and each of the $2 \times n^{[7]}$ moieties shown as $Q^{[7]}$ is independently a radical comprising 1-100 atoms selected from the group C, H, N, O, Si, P and S, containing attachment sites for at least $p^{[6]}$ (for $Q^{[6]}$) or $p^{[7]}/2$ (for $Q^{[7]}$, where $p^{[7]}/2$ is an integer) functional groups on alkyl, alkenyl, or aromatic carbon atoms;

more preferably, all of the $n^{[6]}$ moieties shown as $Q^{[6]}$ are identical;

25 more preferably, all of the $2 \times n^{[7]}$ moieties shown as $Q^{[7]}$ are identical;

more preferably, each of the $n^{[6]}$ moieties shown as $Q^{[6]}$, is independently chosen from the group $CH[(CH_2)_r(\text{attachment site})]_2$ and

30 $CH[(CH_2)_rC(=O)NR^{SUB}(CH_2)_q(\text{attachment site})]_2$, wherein $r=1$ to 10 and $q=1$ to 10;

more preferably, each of the $2 \times n^{[7]}$ moieties shown as $Q^{[7]}$, is independently chosen from the group $(CH_2)_r$,

35 $(CH_2)_rNR^{SUB}C(=O)(CH_2)_q$, $(CH_2)_rC(=O)NR^{SUB}(CH_2)_q$,

-15-

(CH₂)_rNR^{SUB}C(=O)(CH₂)_qNR^{SUB}C(=O)(CH₂)_r,
(CH₂)_rC(=O)NR^{SUB}(CH₂)_qNR^{SUB}C(=O)(CH₂)_r,
(CH₂)_rNR^{SUB}C(=O)(CH₂CH₂O)_qCH₂CH₂, and
5 (CH₂)_rC(=O)NR^{SUB}(CH₂CH₂O)_qCH₂CH₂, wherein r=1 to 10, more preferably r=2 to 6, and q=1 to 10, more preferably q=1 to 3.

Brief Description of the Drawings

10 Figure 1 shows the anti-PN response in mice primed with PN-KLH, treated with [(PN)₂₀-BAHA]-EDDA, Conjugate 17-II, in the doses shown, which were given a booster injection of PN-KLH and then bled 5 days later. Sera were tested at 3 dilutions by the Farr assay using
15 radiolabeled PN at 10⁻⁸ M and the data are presented as the percentage reduction of anti-PN antibodies. There were 5 mice per group.

Figure 2 shows the anti-KLH response in mice primed with PN-KLH, treated with [(PN)₂₀-BAHA]-EDDA, Conjugate
20 17-II, in the doses shown, given a booster injection of PN-KLH and then bled 5 days later. Anti-KLH antibodies were assayed by enzyme-linked immunosorbent assay (ELISA). The results are expressed as the percent of a standard pool of antisera. There were 5 mice per group.

25 Figure 3 shows the anti-PN response in mice primed with PN-KLH, treated with either [(PN)₁₆-BAHA_{ox}]-EDDA (Conjugate 11-IV), [(PN)₂₀-BAHA_{ox}]-EDDA (Conjugate 11-II), [(PN)₂₄-BAHA_{ox}]-EDDA (Conjugate 11-VI) or [(PN)₃₂-BAHA_{ox}]-EDDA (Conjugate 11-VIII) in the doses shown, given a
30 booster injection of PN-KLH and then bled 5 days later. Sera were tested by the Farr assay using radiolabeled PN at 10⁻⁸ M. There were 5 mice per group.

35 Figure 4 shows the anti-PN response in mice primed with PN-KLH, treated with (PN)₂₀-HAD-AHAB-TEG, Conjugate

-16-

20-II, in the doses shown or with HAD-AHAB only, or the
PN only or a mixture of each, then boosted with PN-KLH
and bled 5 days later. Sera were tested by the Farr
5 assay using radiolabeled PN at a concentration of 10^{-8} M.
The percent reduction was calculated and the data are
presented. There were 5 mice per group.

Figure 5 shows the anti-PN response in mice primed
with PN-KLH, treated with $(\text{PN})_{20}$ -HAD_pS-AHAB-TEG, Conjugate
10 20-IV, in the doses shown, then boosted with PN-KLH and
bled 5 days later. Sera were tested by the Farr assay
using radiolabeled PN at a concentration of 10^{-8} M.
There were 5 mice per group.

Figures 6A-B show the structure of the derivatized
15 valency platform molecule and the linker coupling the
polynucleotide to the platform molecule for Conjugates 3-
I, 3-II, 11-I, 11-II, 11-IV, 11-VI, 11-VIII, 17-I, 17-II,
20-I, 20-II, 20-III, and 20-IV.

Figure 7 shows the structures of the derivatized
20 valency platform molecule "HAD-AHAB-TEG."

Figure 8 compares the level of T cell proliferation
induced by melittin peptides.

Figure 9 compares the levels of anti-melittin
peptide 2 antibodies produced in mice treated with
25 melittin peptide Conjugate 2 versus the control mice
treated with formulation buffer.

Figure 10 compares the levels of anti-melittin
antibodies produced in mice treated with melittin peptide
Conjugate 2 versus the control mice treated with
30 formulation buffer.

Figure 11 compares the levels of anti-melittin
peptide 2 antibody-forming cells in mice treated
with melittin peptide Conjugate 2 versus the control mice
35 treated with formulation buffer.

-17-

Figure 12 illustrates that melittin peptide Conjugate 4, a conjugate of peptide #5 which contains a T cell epitope, was not a tolerogen.

5 Figure 13 illustrates melittin conjugates within the present invention.

Figure 14 illustrates the increase in the percentage of reduction in anti-dsPN antibody achieved by conjugates within the present invention LJP-249A and LJP-249B which are Conjugate 3-II compared to a prior art conjugate (LJP-105) comprising D-EK and (PN)₅₀.

Figure 15 illustrates the suppression of serum circulating IgG anti-DNA antibodies in male BXSB mice treated with LJP-394, Conjugate 20-II. An ELISA assay was used to measure IgG antibodies to (PN)₅₀ conjugated to D-EK. The serum from each of eight individual mice in each group was assayed.

Modes for Carrying Out the Invention

20 As used herein "valency platform molecule" means a chemically-defined, non-polymeric, nonimmunogenic molecule containing sites which facilitate the attachment of a discreet number of biological and/or chemical molecules.

25 "Nonimmunogenic" is used to describe the valency platform molecule and means that the valency platform molecule elicits substantially no immune response when it is administered by itself to an individual.

30 As used herein "individual" denotes a member of the mammalian species and includes humans, primates, mice and domestic animals such as cattle and sheep, sports animals such as horses, and pets such as dogs and cats.

35 As used herein the term "immunogen" means a chemical entity that elicits a humoral immune response when

-18-

injected into an animal. Immunogens have both B cell epitopes and T cell epitopes.

5 The term "analog" of an immunogen intends a molecule that (a) binds specifically to an antibody to which the immunogen binds specifically and (b) lacks T cell epitopes. Although the analog will normally be a fragment or derivative of the immunogen and thus be of the same chemical class as the immunogen (e.g., the
10 immunogen is a polypeptide and the analog is a polypeptide), chemical similarity is not essential. Accordingly, the analog may be of a different chemical class than the immunogen (e.g., the immunogen is a carbohydrate and the analog is a polypeptide) as long as
15 it has the functional characteristics (a) and (b) above. The analog may be a protein, carbohydrate, lipid, lipoprotein, glycoprotein, lipopolysaccharide, nucleic acid or other chemical or biochemical entity.

An analog of an immunogen may also comprise a
20 "mimotope." The term "mimotope" intends a synthetic molecule which competitively inhibits the antibody from binding the immunogen. Because it specifically binds the antibody, the mimotope is considered to mimic the antigenic determinants of the immunogen. Like an analog
25 of an immunogen, a mimotope (a) binds specifically to an antibody to which the immunogen binds specifically and (b) lacks T cell epitopes.

An analog of an immunogen may also comprise an
30 "aptamer." The term "aptamer" intends a synthetic oligonucleotide which competitively inhibits the antibody from binding the immunogen. Like an analog of an immunogen, an aptamer (a) binds specifically to an antibody to which the immunogen binds specifically and
35 (b) lacks T cell epitopes.

-19-

As used herein the term "B cell anergy" intends unresponsiveness of those B cells requiring T cell help to produce and secrete antibody and includes, without
5 limitation, clonal deletion of immature and/or mature B cells and/or the inability of B cells to produce antibody. "Unresponsiveness" means a therapeutically effective reduction in the humoral response to an immunogen. Quantitatively the reduction (as measured by
10 reduction in antibody production) is at least 50%, preferably at least 75%, and most preferably 100%.

"Antibody" means those antibodies whose production is T cell dependent.

The valency of a chemically-defined valency platform
15 molecule within the present invention can be predetermined by the number of branching groups added to the platform molecule. Suitable branching groups are typically derived from diamino acids, triamines, and amino diacids. A conjugate within the instant invention
20 is biologically stabilized; that is, it exhibits an in vivo excretion half-life of hours to days to months to confer therapeutic efficacy. The chemically-defined valency platform molecules of the instant invention are also substantially nonimmunogenic (i.e., they exhibit no
25 or only mild immunogenicity when administered to animals), non-toxic at the doses given (i.e., they are sufficiently non-toxic to be useful as therapeutic agents) and are preferably composed of a defined chemical structure. They provide a non-immunogenic, non-toxic
30 polyfunctional substrate to which a multiplicity of biological or chemical molecules such as polynucleotide duplexes may be attached covalently. They will normally have an average molecular weight in the range of about
35 200 to about 200,000, usually about 200 to about 20,000,

-20-

and are homogeneous as compared to the prior art polymers which were a mixture of compounds of widely fluctuating molecular weight. Examples of particularly preferred, homogenous valency platform molecules within the present invention are derivatized 2,2'-ethylenedioxydiethylamine (EDDA), triethylene glycol (TEG) and polyethylene glycols (PEGs) having a molecular weight of about 200 to about 8,000.

Conjugation of a biological or chemical molecule to the chemically-defined platform molecule may be effected in any number of ways, typically involving one or more crosslinking agents and functional groups on the biological or chemical molecule and valency platform molecule.

The synthetic polynucleotide duplexes that are coupled to the valency platform molecule are composed of at least about 20 bp and preferably 20-50 bp. Polynucleotides described herein are deoxyribonucleotides unless otherwise indicated and are set forth in 5' to 3' orientation. Preferably the duplexes are substantially homogeneous in length; that is, the variation in length in the population will not normally exceed about $\pm 20\%$, preferably $\pm 10\%$, of the average duplex length in base pairs. They are also preferably substantially homogeneous in nucleotide composition; that is, their base composition and sequence will not vary from duplex to duplex more than about 10%. Most preferably they are entirely homogeneous in nucleotide composition from duplex to duplex.

Based on circular dichroic (CD) spectra interpretation, the duplexes that are useful in the invention assume a B-DNA type helical structure. It should be understood that it is not intended that the

-21-

invention be limited by this belief and that the duplexes may, upon more conclusive analysis assume Z-DNA and/or A-DNA type helical structures.

5 These polynucleotide duplexes may be synthesized from native DNA or synthesized by chemical or recombinant techniques. Naturally occurring or recombinantly produced dsDNA of longer length may be digested (e.g., enzymatically, chemically or by mechanical shearing) and
10 fractionated (e.g., by agarose gel or Sephadex® column) to obtain polynucleotides of the desired length.

 Alternatively, pairs of complementary single-stranded polynucleotide chains up to about 70 bases in length are readily prepared using commercially
15 available DNA synthesizers and then annealed to form duplexes by conventional procedures. Synthetic dsDNA of longer length may be obtained by enzymatic extension (5'-phosphorylation followed by ligation) of the chemically produced shorter chains.

20 The polynucleotides may also be made by molecular cloning. For instance, polynucleotides of desired length and sequence are synthesized as above. These polynucleotides may be designed to have appropriate termini for ligation into specific restriction sites.
25 Multiple iterations of these oligomers may be ligated in tandem to provide for multicopy replication. The resulting construct is inserted into a standard cloning vector and the vector is introduced into a suitable microorganism/cell by transformation. Transformants are
30 identified by standard markers and are grown under conditions that favor DNA replication. The polynucleotides may be isolated from the other DNA of the cell/microorganism by treatment with restriction enzymes

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-22-

and conventional size fractionation (e.g., agarose gel, Sephadex® column).

Alternatively, the polynucleotides may be replicated
5 by the polymerase chain reaction (PCR) technology.
Saiki, R.K, et al., Science (1985) 230:1350; Sacki, et
al., Science (1988) 239:487; Sambrook, et al., In
Molecular Cloning Techniques: A Laboratory Manual, Vol.
12, p 14.1-14.35 Cold Spring Harbor Press (1989).

10 Polynucleotides may be screened for binding activity
with SLE antisera by the assays described in the
examples. The modified Farr assay in which binding
activity may be expressed as I_{50} (the polynucleotide
concentration in molar nucleotides resulting in
15 half-maximal inhibition) is a preferred assay.
Polynucleotide duplexes having an I_{50} of less than about
500 nM, preferably less than 50 nM, are deemed to have
significant binding activity and are, therefore, useful
for making the conjugates of this invention.

20 The polynucleotides are conjugated to the
chemically-defined valency platform molecule in a manner
that preserves their antibody binding activity. This is
done by conjugating the polynucleotide to the valency
platform molecule at a predetermined site on the
25 polynucleotide chain such that the polynucleotide forms a
pendant chain of at least about 20 base pairs measured
from the conjugating site to the free (unattached) end of
the chain.

In a particularly preferred embodiment, the
30 polynucleotides of the invention conjugates are coupled
to a linker molecule at or proximate one of their ends.
The linker molecule is then coupled to the chemically-
defined valency platform molecule. For example, a
35 defined double-stranded PN can be conjugated to a valency

-23-

platform molecule by first providing a single chain
consisting of approximately 20 alternating cytosine (C)
and adenosine (A) nucleotides. Four CA chains can then
5 be covalently conjugated through linkers such as HAD to
four reactive sites on a derivatized platform molecule
such as triethylene glycol. The valency platform
molecule is synthesized to include groups such as
bromoacetyl. During the conjugation, a leaving group is
10 displaced by sulfur. A second single nucleotide chain
consisting of approximately 20 alternating thymidine (T)
and guanosine (G) nucleotides can then be annealed to the
CA strand to form a double-stranded PN conjugate of the
formula, $[(PN)_{20}\text{-linker}]_4\text{-valency platform molecule}$.

15 Alternatively, in another preferred embodiment, the
polynucleotide may be coupled to the derivatized valency
platform molecule at the 3' end of the polynucleotide via
a morpholino bridge formed by condensing an oxidized 3'
terminal ribose on one of the strands of the
20 polynucleotide with a free amino group on the derivatized
platform molecule and then subjecting the adduct to
reducing conditions to form the morpholino linkage. Such
coupling requires the derivatized platform molecule to
have at least an equal number of amino groups as the
25 number of polynucleotide duplexes to be bound to the
platform molecule. The synthesis of such a conjugate is
carried out in two steps. The first step is coupling one
strand of the polynucleotide duplex to the derivatized
platform molecule via the condensation/reduction reaction
30 described above. The oxidized 3' terminal ribose is
formed on the single polynucleotide strand by treating
the strand with periodate to convert the 3' terminal
ribose group to an oxidized ribose group. The
35 single-stranded polynucleotide is then added slowly to an

-24-

aqueous solution of the derivatized platform molecule with a pH of about 6.0 to 8.0 at 2-8°C. The molar ratio of polynucleotide to platform molecule in all the conjugation strategies will normally be in the range of about 2:1 to about 30:1, usually about 2:1 to about 8:1 and preferably about 4:1 to 6:1. In this regard, it is preferable that the conjugate not have an excessively large molecular weight as large molecules, particularly those with repeating units, of m.w. > 200,000 may be T-independent immunogens. See Dintzis et al., J. Immun. (1983) 131:2196 and J. Immun. (1989) 143:1239. During or after the condensation reaction (normally a reaction time of 24 to 48 hr), a strong reducing agent, such as sodium cyanoborohydride, is added to form the morpholino group. The complementary strand of the duplex is then added to the conjugate and the mixture is heated and slowly cooled to cause the strands to anneal. The conjugate may be purified by gel permeation chromatography.

An alternative to the ribose strategy is forming aldehyde functionalities on the polynucleotides and using those functionalities to couple the polynucleotide to the platform molecule via reactive functional groups thereon. Advantage may be taken of the fact that gem, vicinal diols, attached to the 3' or 5' end of the polynucleotide, may be oxidized with sodium periodate to yield aldehydes which can condense with functional amino groups of the platform molecule. When the diols are in a ring system, e.g., a five-membered ring, the resulting condensation product is a heterocyclic ring containing nitrogen, e.g., a six-membered morpholino or piperidino ring. The imino-condensation product is stabilized by reduction with a suitable reducing agent; e.g., sodium borohydride or sodium cyanoborohydride. When the diol is acyclic,

-25-

the resulting oxidation product contains just one aldehyde and the condensation product is a secondary amine.

5 Another procedure involves introducing alkylamino or alkylsulfhydryl moieties into either the 3' or 5' ends of the polynucleotide by appropriate nucleotide chemistry, e.g., phosphoramidate chemistry. The nucleophilic groups may then be used to react with a large excess of
10 homobifunctional cross-linking reagent, e.g., dimethyl suberimide, in the case of alkylamine derivatives, or an excess of heterobifunctional cross-linking reagent, e.g., m-maleimidobenzoyl-N-hydroxysuccinimide ester (MBS) or succinimidyl (4-iodoacetyl) aminobenzoate (SIAB), for
15 the alkylsulfhydryl derivatives. Once excess cross-linker is removed, the polynucleotide derivatives are reacted with amino groups on the platform molecule. Alternatively, the sulfhydryl group may be reacted with an electrophilic center on the platform, such as a
20 maleimide or α -haloacetyl group or other appropriate Michael acceptor.

Still another strategy employs modified nucleosides. Suitable deoxynucleoside derivatives can be incorporated, by standard DNA synthetic chemistry, at desired positions
25 in the polynucleotide, preferably on the 5' or 3' ends. These nucleoside derivatives may then react specifically and directly with alkylamino groups on the platform molecule. Alternatively, side reactions seen with the above-described dialdehyde chemistry, such as amine
30 catalyzed beta-elimination, can be circumvented by employing appropriate nucleoside derivatives as the 3' terminus of the chain to be attached. An example of this is 5' methylene extension of ribose; i.e., a
35 5' (2-hydroxyethyl)- group instead of a 5' hydroxymethyl

-26-

group. An alternative would be to use a phosphonate or phosphinate linkage for the 3' terminal dinucleotide of the polynucleotide to be attached to the platform molecule.

Analog of Immunogens

Immunogens that are involved in antibody-mediated pathologies may be external (foreign to the individual) immunogens such as allergens, α -sperm associated with male infertility, the rheumatic fever carbohydrate complex, the RBC Rh/D antigen associated with hemolytic disease of the newborn, biological drugs, including native biological substances foreign to the individual such as therapeutic proteins, peptides and antibodies, and the like or self-immunogens (autoimmunogens) such as those associated with thyroiditis (thyroglobulin), stroke (cardiolipin) and myasthenia gravis (acetylcholine receptor).

Analog to such immunogens may be identified by screening candidate molecules to determine whether they (a) bind specifically to serum antibodies to the immunogen and (b) lack T cell epitopes. Specific binding to serum antibodies may be determined using conventional immunoassays and the presence or absence of T cell epitopes may be determined by conventional T cell activation assays. In this regard, an analog which "binds specifically" to serum antibodies to the immunogen exhibits a reasonable affinity thereto. Further in this regard, it should be recognized that testing for T cell epitopes is conducted on a subject-by-subject basis using T cells taken from an intended recipient or from various patients that represent the target population of recipients. The presence or absence of T cell epitopes

-27-

may be determined using the tritiated thymidine incorporation assay described in the examples. The presence of T cell epitopes can also be determined by measuring secretion of T cell-derived lymphokines by methods well known in the art. Analogs that fail to induce statistically significant incorporation of thymidine above background are deemed to lack T cell epitopes. It will be appreciated that the quantitative amount of thymidine incorporation may vary with the immunogen. Typically a stimulation index below about 2-3, more usually about 1-2, is indicative of a lack of T cell epitopes.

A normal first step in identifying useful analogs is to prepare a panel or library of candidates to screen. For instance, in the case of protein or peptide analogs, libraries may be made by synthetic or recombinant techniques such as those described by Geysen et al. in Synthetic Peptides as Antigens; Ciba Symposium (1986) 119:131-149; Devlin et al., Science (1990) 249:404-406; Scott et al., Science (1990) 249:386-390; and Cwirla et al., PNAS USA (1990) 87:6378-6382. In one synthetic technique, peptides of about 5 to 30 amino acids are synthesized in such a manner that each peptide overlaps the next and all linear epitopes are represented. This is accomplished by overlapping both the carboxyl and amino termini by one less residue than that expected for a B cell epitope. For example, if the assumed minimum requirement for a B cell epitope is six amino acids, then each peptide must overlap the neighboring peptides by five amino acids. In this embodiment, each peptide is then screened against antisera produced against the native immunogen, either by immunization of animals or from patients, to identify the presence of B cell

-28-

epitopes. Those molecules with antibody binding activity are then screened for the presence of T cell epitopes as described in the examples. The molecules lacking T cell epitopes are useful as analogs in the invention.

If the T cell epitope(s) of an immunogen are known or can be identified, random T cell screening of candidate analogs is not necessary. In such instances, the T cell epitope(s) may be altered (e.g., by chemical derivatization, or elimination of one or more components of the epitope) to render them inoperative or be eliminated completely, such as, for instance, in the case of peptides, by synthetic or recombinant procedures.

Mimotopes and aptamers are synthesized by conventional methods and are screened in the same manner as other analogs of immunogens.

The analogs are coupled to a nonimmunogenic valency platform molecule to prepare the conjugates of the invention. Conjugates comprising valency platform molecules and biologically active molecules such as carbohydrates, lipids, lipopolysaccharides, proteins, glycoproteins, drugs, and analogs of interest are synthesized utilizing the chemistries exemplified herein. A preferred method of synthesis is to incorporate a linker molecule on the biological molecule by well known methods chosen on a case-by-case basis.

When conjugating drugs such as adriamycin (doxorubicin) to a valency platform molecule, the amino group on a sugar ring can react with platform molecules containing active esters. Adriamycin can also be modified to contain thiol groups for conjugation to a haloacetylated platform (Kaneko, T., et al., Bioconjugate Chemistry, 2:133 (1991)).

-29-

Carbohydrates such as oligosaccharides can be modified to contain a sulfhydryl-containing linker (Wood, S.J. and Wetzel, R., Bioconjugate Chemistry, 3:391 (1992)). The sulfhydryl group is used for conjugation to a haloacetylated platform. Alternatively, carbohydrates can be oxidized to generate aldehydes which is reacted in the presence of NaCNBH₃ with amino platforms to form conjugates.

Lipids such as glycol-lipids containing an ethanolamine group are reacted with an activated carboxylate on the platform. Lipopolysaccharides containing sugar units are oxidized to generate aldehydes which are reacted in the presence of NaCNBH₃ with amino platforms to form conjugates by reductive amination.

In the case of additional proteins such as Fab' antibody fragments, sulfhydryl groups on the protein (Fab') are conjugated to a platform via haloacetyl groups. Glycoproteins are modified with a thiol linker using iminothiolate. The thiol reacts with platforms containing haloacetyl groups.

The ability of the conjugates to act as tolerogens and specifically suppress production of antibodies may be evaluated in the murine model described in the examples.

The conjugates will normally be formulated for administration by injection, (e.g., intraperitoneally, intramuscularly, intravenously etc.). Accordingly, they will typically be combined with pharmaceutically acceptable aqueous carriers such as saline, Ringer's solution, dextrose solution, and the like. The conjugate will normally constitute about 0.01% to 10% by weight of the formulation. The conjugate is administered to an individual in amounts sufficient to at least partially reestablish tolerance to the autoantigens causing SLE.

-30-

Such amounts are sometimes herein referred to as
"therapeutically effective" amounts. The particular
dosage regimen i.e., dose, timing and repetition, will
depend upon the particular individual, and that
individual's medical history. Normally a dose of about 1
to 1000 μ g conjugate/kg body weight will be given.
Repetitive administrations may be required to achieve
and/or maintain a state of immune tolerance.

The following examples further illustrate the
invention and its unexpectedness relative to the prior
art. These examples are not intended to limit the
invention in any manner.

Example 1

The following reaction schemes illustrate methods of
synthesizing derivatized chemically-defined valency
platform molecules within the present invention. In this
example, DMTr=dimethoxytrityl; Tr=trityl; Bz=benzoyl;
Cp=deoxycytidine monophosphate, CE=cyanoethyl;
CPG=controlled pore glass, DMF = dimethyl formamide, DCC
= dicyclohexylcarbodiimide, TFA = trifluoroacetic acid,
CDI = carbonyl diimidazole, Ts = tosyl (para-toluene
sulfonyl), DIPAT = diisopropyl ammonium tetraazolidine,
TBDMSCl = tetrabutyl dimethyl silyl chloride, TBAF =
tetrabutyl ammonium fluoride, NMMO = N-methylmorpholine
oxide.

-31-

Reaction Scheme 1

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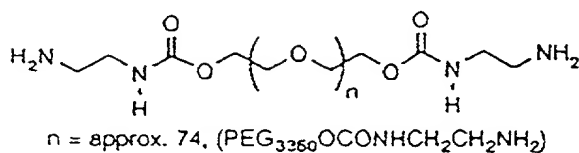
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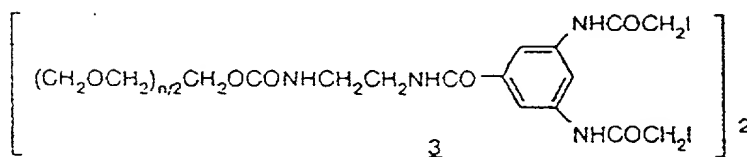
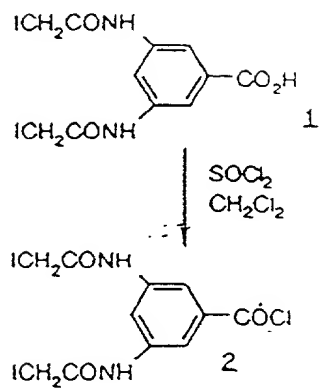
30

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3,5- diamino benzoic acid $\xrightarrow{\text{iodoacetic anhydride}}$



DMF/H₂O
NaHCO₃

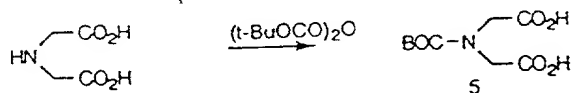
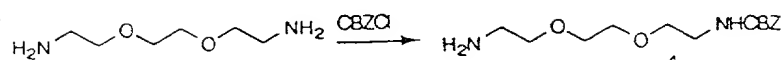


IA-DABA-PEG

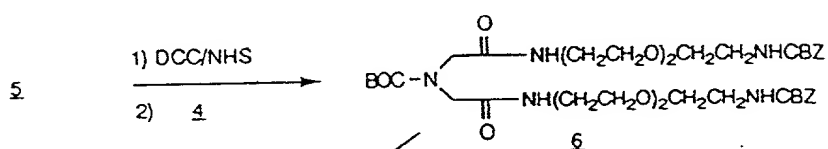
-32-

Reaction Scheme 2

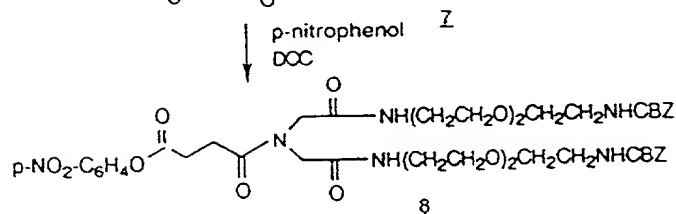
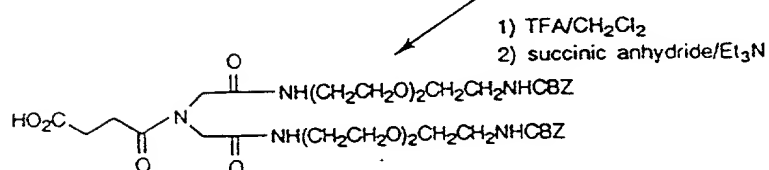
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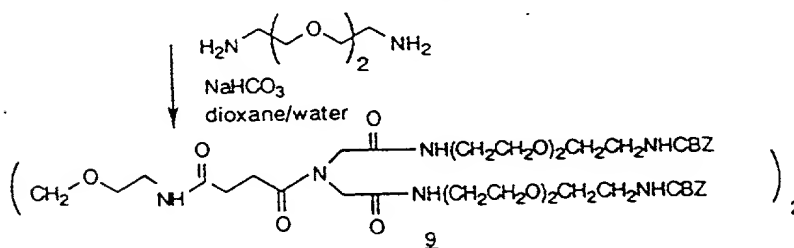
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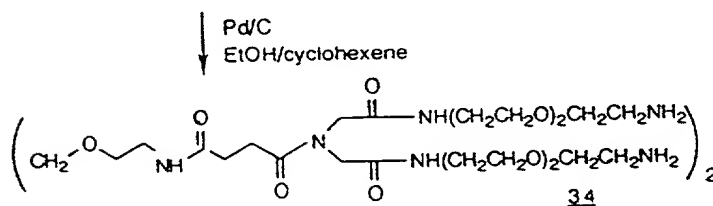
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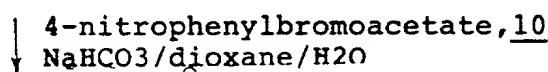
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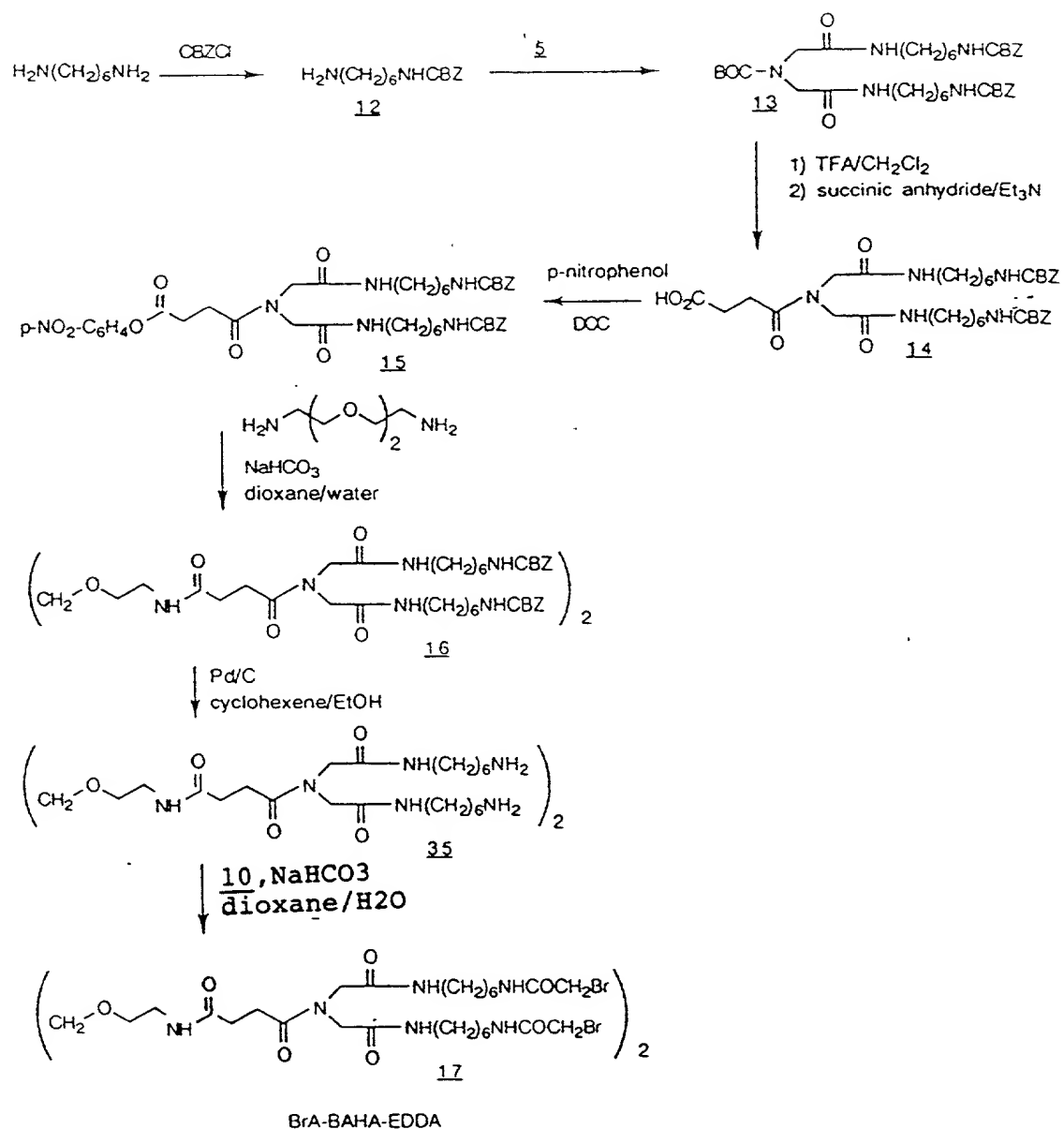


35

BrA-BAHA_{ox}-EDDA

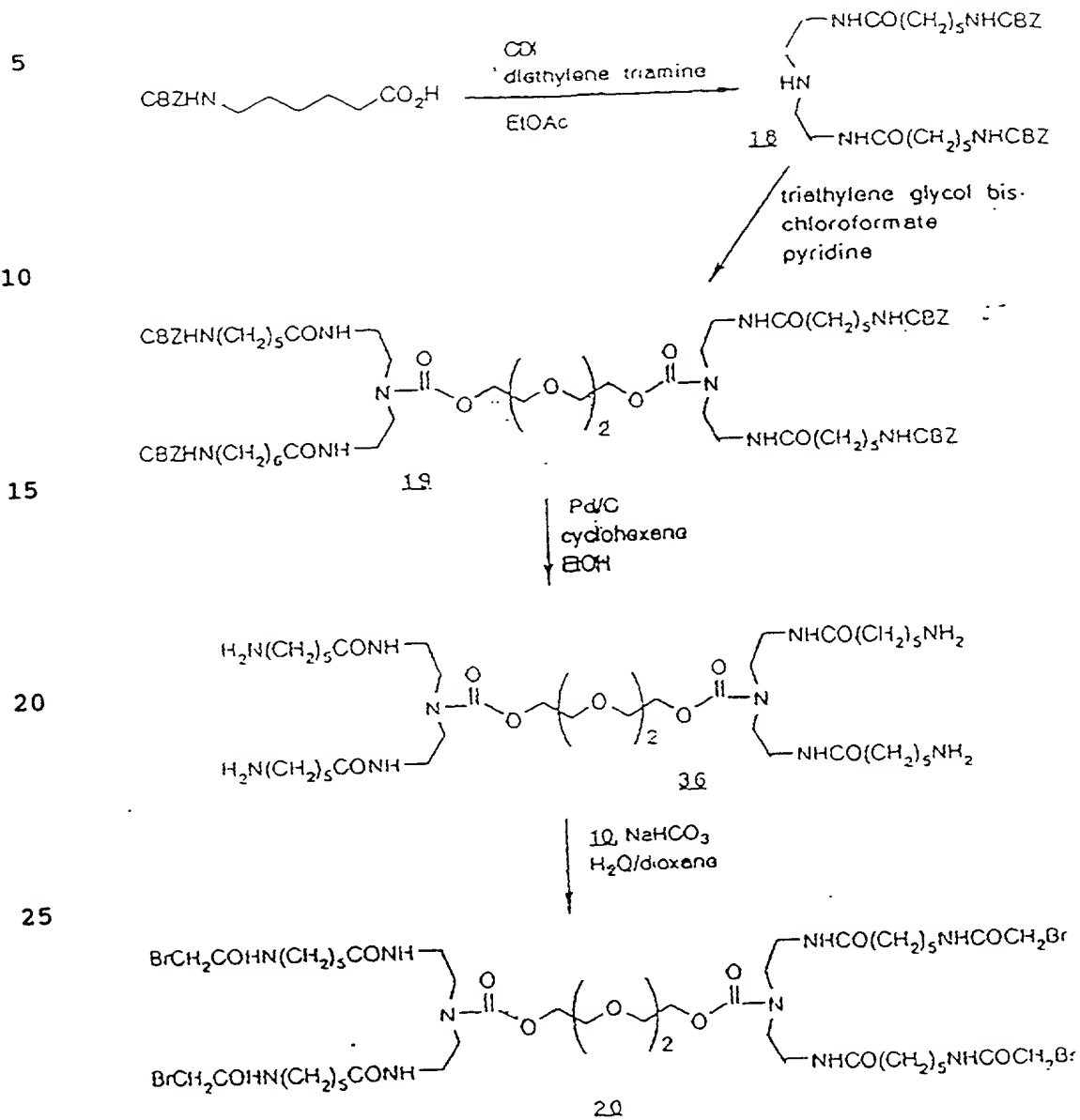
-33-

Reaction Scheme 3



-34-

Reaction Scheme 4

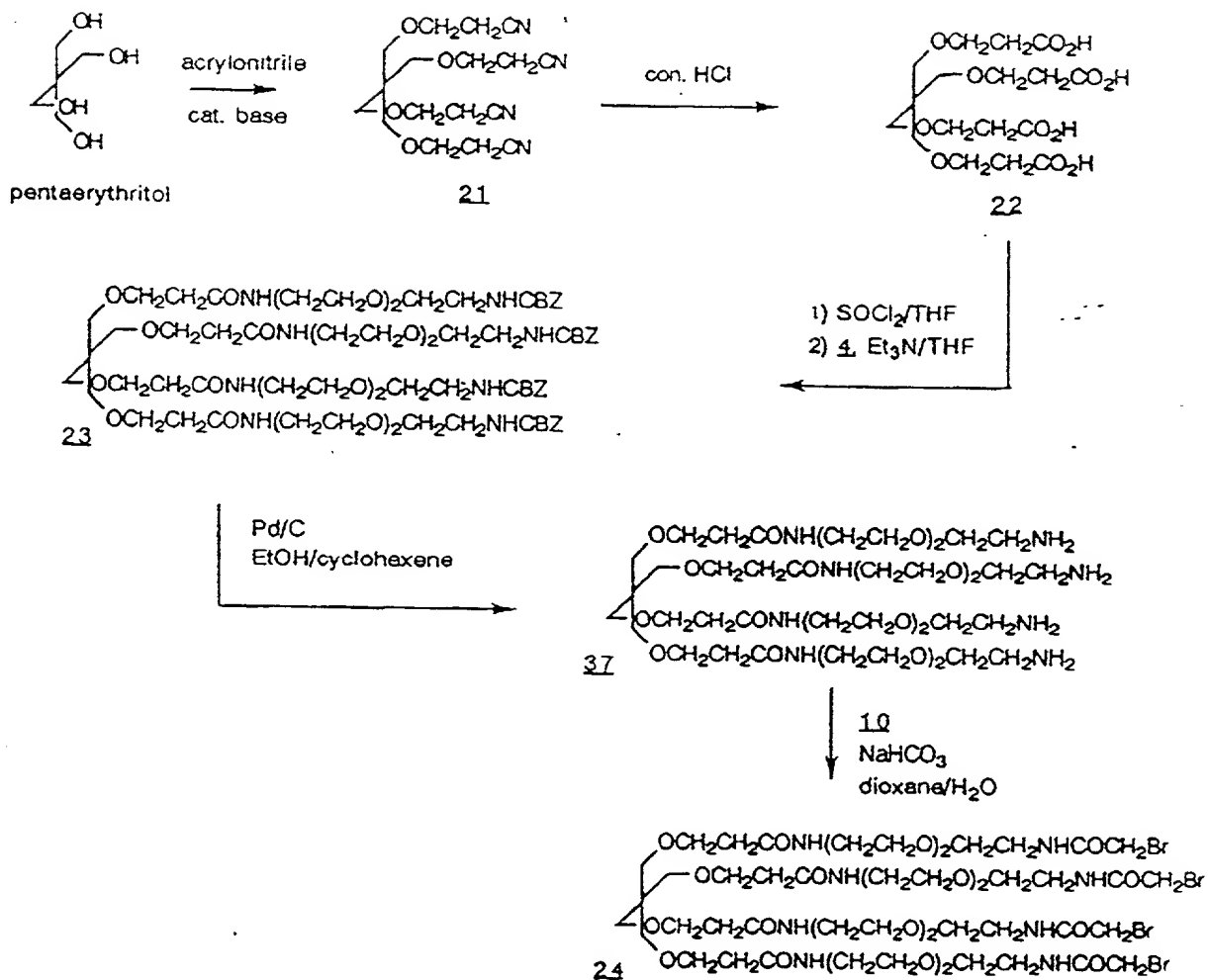


BrA - AHAB - TEG

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-35-

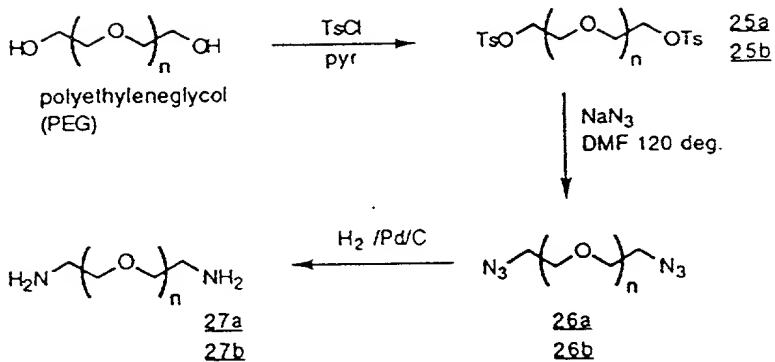
Reaction Scheme 5



Reaction Scheme 6

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$n = \text{approx. } 74$ (PEG average MW = approx. 3350)
 $n = \text{approx. } 200$ (PEG average MW = approx. 8000)

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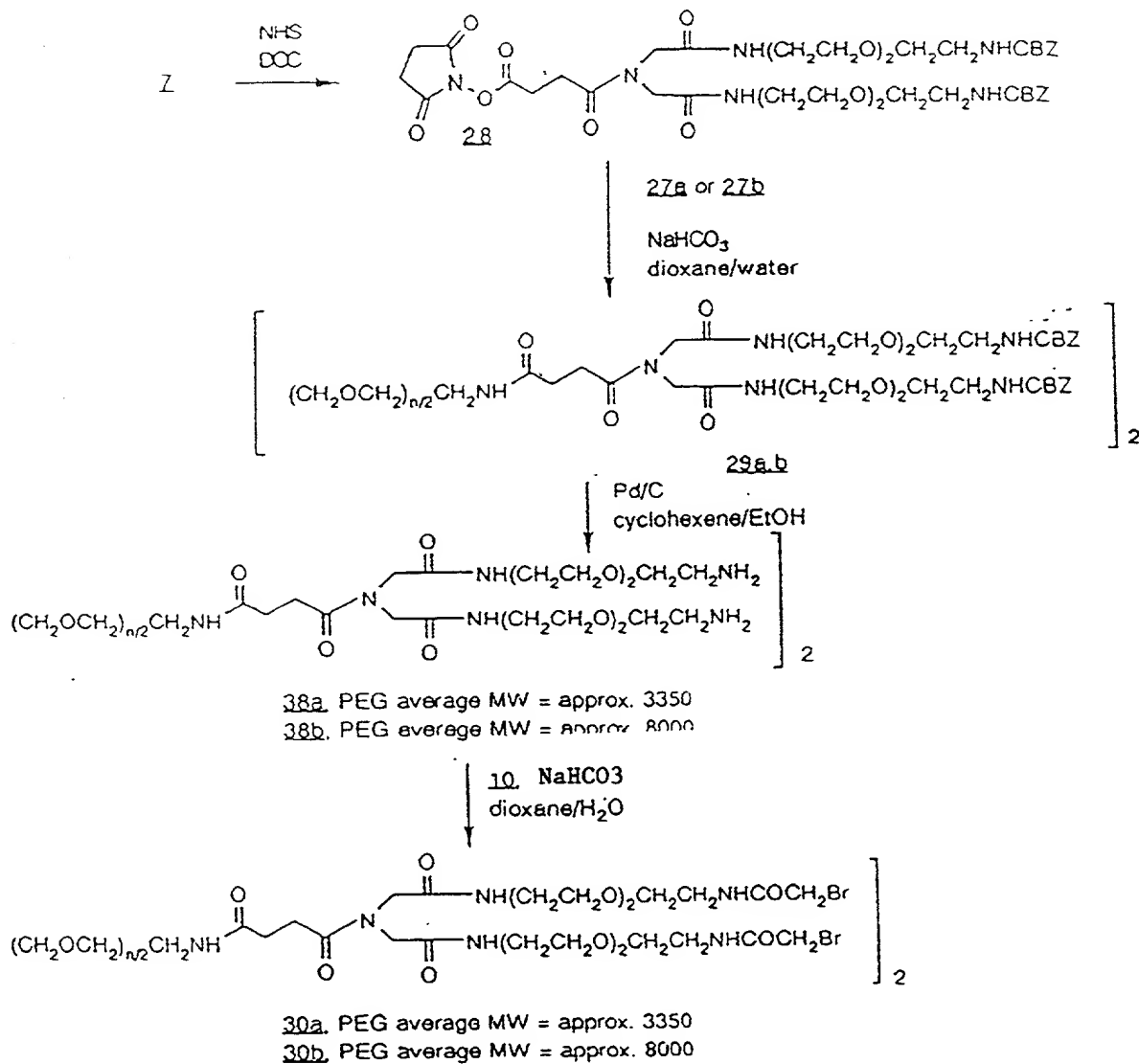
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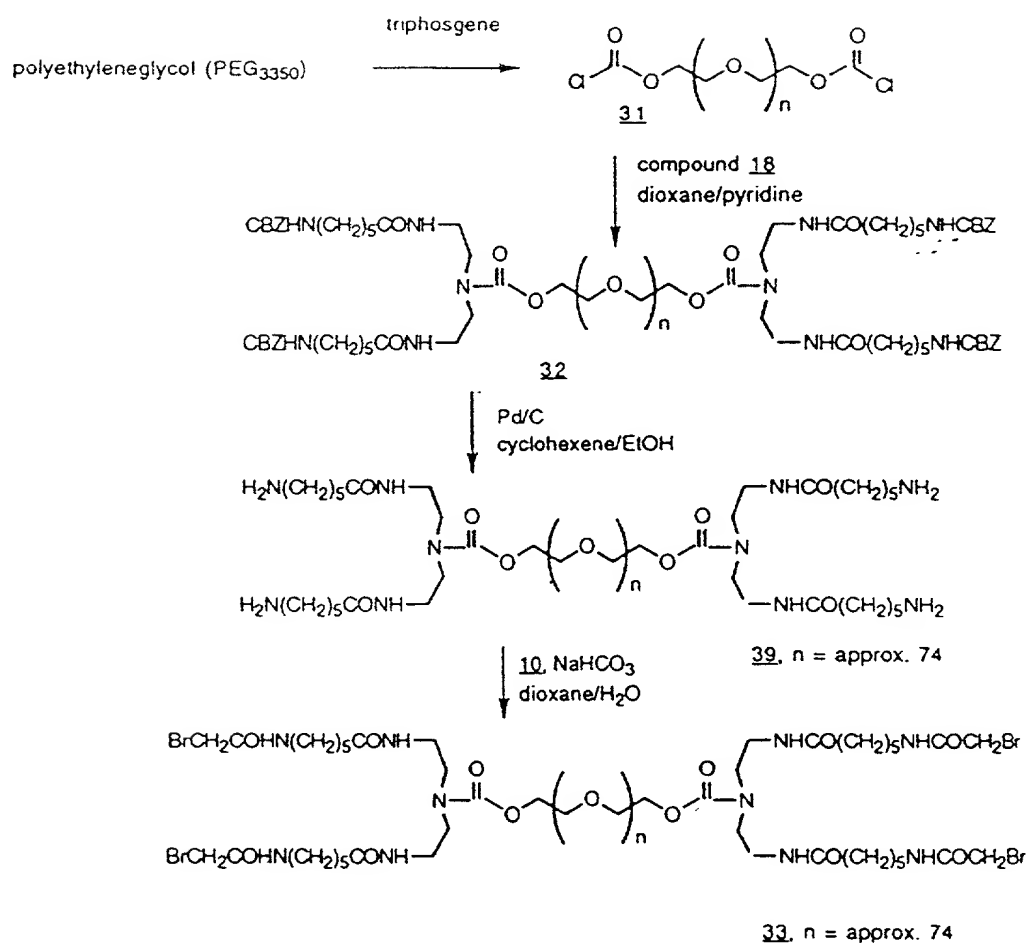
-37-

Reaction Scheme 7



-38-

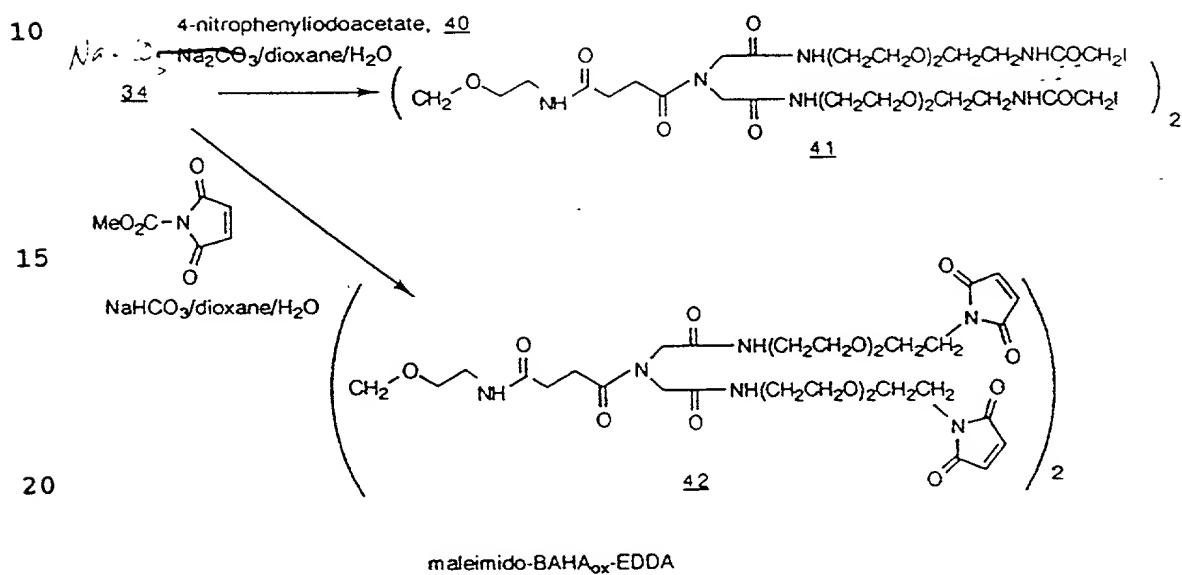
Reaction Scheme 8



BrA - AHAB - PEG

Reaction Scheme 9

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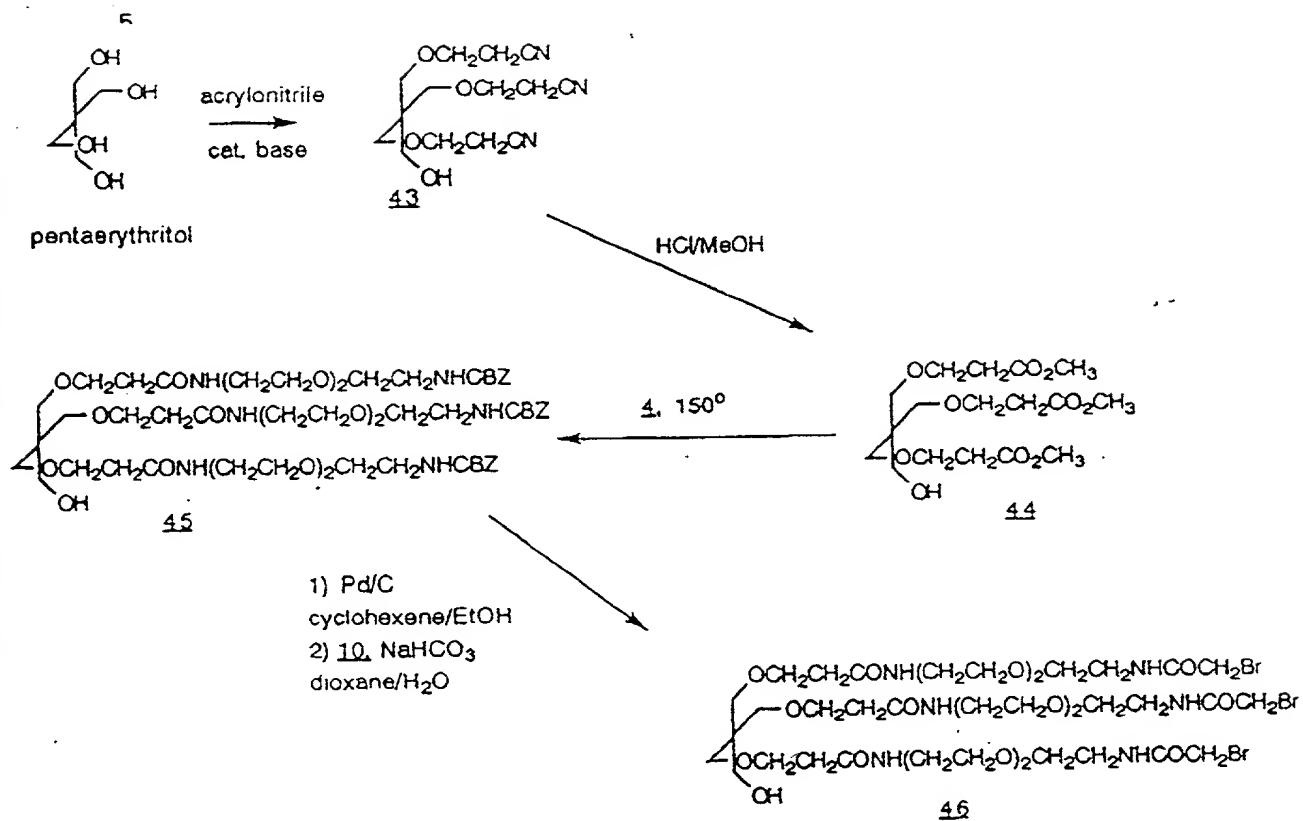


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Reaction Scheme 10



-41-

Synthesis of reagents used to modify (CA)₈, (CA)₁₀, (CA)₁₂ and (CA)₁₆ with disulfide linkers is described in Reaction Scheme 11 below:

Reaction Scheme 11

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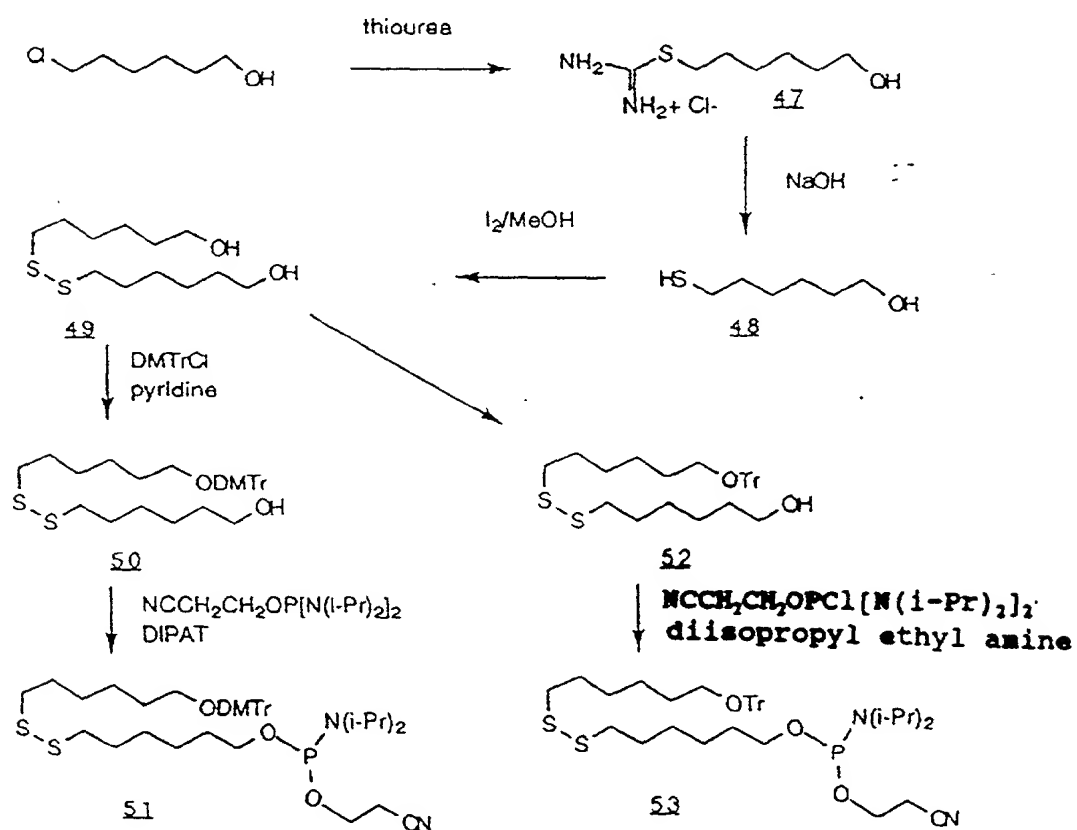
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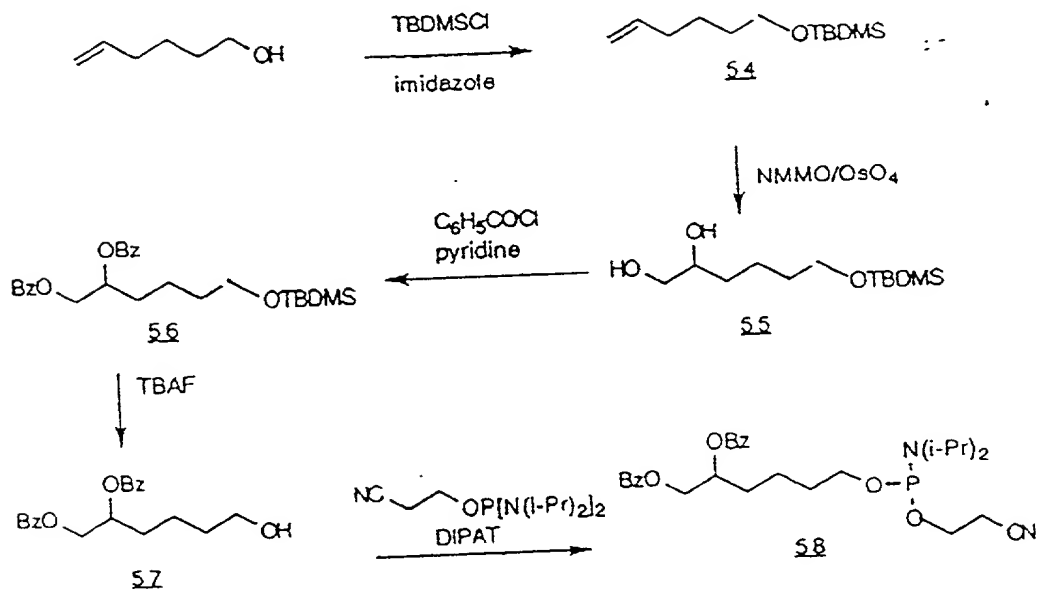
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-42-

Synthesis of a reagent used to modify (CA)₂₅ with vicinal diol linkers is described in Reaction Scheme 12 below:

Reaction Scheme 12



-43-

Reaction Scheme 13

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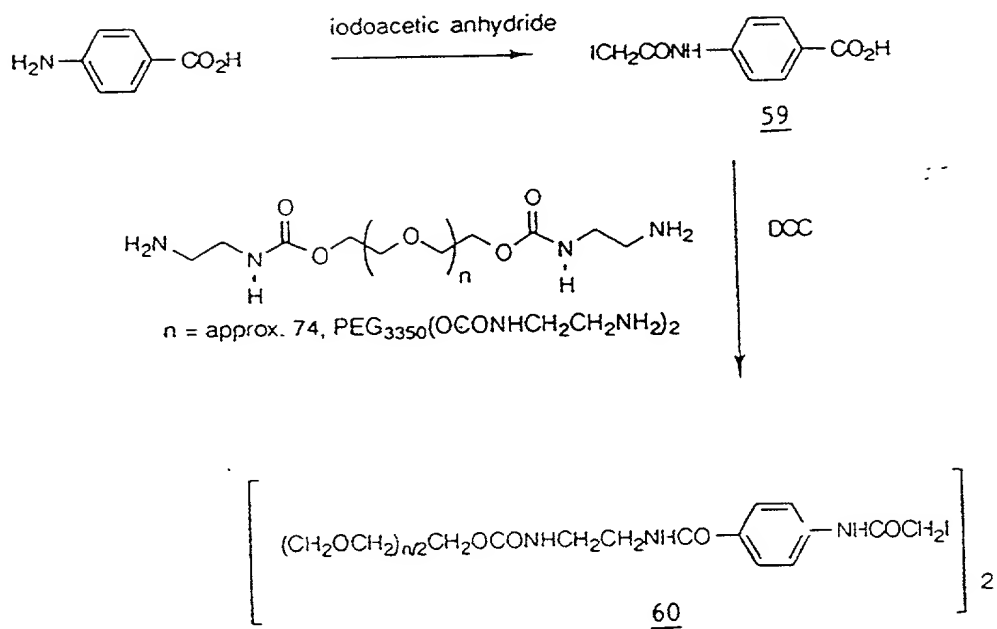
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Example 2
Synthesis of Chemically-Defined
Valency Platform Molecules

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Compound 1 - [3,5-Bis-(iodoacetamido)benzoic acid]: 2.93 g (8.28 mmol, 2.2 eq) of iodoacetic anhydride was added to a stirred suspension of 572 mg (3.76 mmol) of 3,5-diaminobenzoic acid in 19 mL of dioxane at room temperature under N₂ atmosphere. The mixture was stirred, covered with foil for 20 hours and partitioned between 50 mL of EtOAc and 50 mL of 1N HCl solution. The EtOAc layer was washed with brine, dried over MgSO₄, filtered, and concentrated on a rotary evaporator to give 3.3 g of tan solid. The material was purified by silica gel chromatography (94/5/1 CH₂Cl₂/MeOH/HOAc) to yield 992 mg (54%) of compound 1 as a white solid: NMR (DMSO) 3.84 (s, 4H), 7.91 (s, 2H), 8.14 (s, 1H), 10.56 (s, 2H).

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Compound 2 - [3,5-Bis-(iodoacetamido)benzoyl chloride]: 117 µL (1.6 mmol, 190 mg) of SOCl₂ was added to a solution of 390 mg (0.8 mmol) of 1 in 34 mL of THF. The mixture was refluxed under N₂ atmosphere until all solids had dissolved (approximately 30 minutes) to give a clear red-brown solution. The mixture was concentrated on the rotary evaporator and placed under vacuum to provide crude compound 2 as a foamy solid which was used directly in the next step.

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Compound 3 - [N,N'-Bis-(3,5-bis-(iodoacetamido)benzoyl) derivative of α,ω-bis-(N-2-aminoethylcarbamoyl)polyethyleneglycol]: 570 mg of α,ω-bis-(N-2-aminoethylcarbamoyl)polyethyleneglycol (0.16 mmol, 3350 g/mol, Sigma) was placed in a tared flask.

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-45-

Toluene (20 mL) was added and water was removed by azeotropic distillation. The residue was dried under vacuum to give 549 mg of solid and dissolved in 4 mL THF with 89 μ L (0.64 mmol) of diisopropylethylamine. The crude acid chloride was dissolved in 4 mL anhydrous THF and added to the mixture over 30 seconds under N_2 . The mixture was stirred for 16 hours at room temperature and partitioned between 25 mL of 0.1 N HCl and 25 mL of CH_2Cl_2 . The aqueous layer was again extracted with CH_2Cl_2 and the organic layers were combined, washed with 25 mL of H_2O , followed by 50 mL of a $NaHCO_3$ solution. The organic layers were dried with Na_2SO_4 , filtered, and concentrated to give 784 mg of orange oil. Silica gel chromatography (9/1 CH_2Cl_2 /MeOH) yielded 190 mg of colorless oil which was crystallized from hot EtOH/Et₂O, collected on sintered glass filter under N_2 pressure, and dried under vacuum to provide 177 mg of compound 3 as a white solid: NMR ($CDCl_3$) 3.40 (bd m, 8H), 3.59 (bd s, $(CH_2CH_2O)_n$, integral too large to integrate in relation to other integrals), 3.91 (s, 8H), 4.21 (m, 4H), 6.04 (bd m, 2H), 7.55 (bd m, 2H), 7.78 (bd s, 4H), 8.10 (bd s, 2H), 9.30 (bd m, 4H): iodoacetyl determination (European Journal of Biochemistry (1984) 140:63-71): Calculated, 0.92 mmol/g; Found, 0.96 mmol/g.

Compound 4 - [Mono-N-carbobenzyloxy-3,6-dioxa-1,8-diaminooctane]: A solution of 14.3 mL (17.1 g, 100 mmol) of benzylchloroformate in 200 mL of CH_2Cl_2 was added dropwise over a 1 hour period to a solution of 29.0 mL (29.6 g, 200 mmol) of 2,2'-(ethylenedioxy)-diethylamine (Fluka) in 100 mL of CH_2Cl_2 at 0°. The mixture was stirred at room temperature for 24 hours and 1 N HCl was added until the aqueous layer remained acidic (pH less

-46-

than 2). The aqueous layer was washed with three 50 mL portions of CH_2Cl_2 and neutralized with 1 N NaOH until the pH was above 13. The basic aqueous layer was extracted with five 75 mL portions of CH_2Cl_2 . The combined CH_2Cl_2 layers were dried (MgSO_4), filtered, and concentrated to yield 12.7 g (45%) of compound 4 as a thick oil: ^1H NMR (CDCl_3) d 2.82 (bd s, 2H), 3.30-3.60 (m, 12H), 5.10 (s, 2H), 5.75 (bd s, 1H), 7.20-7.40 (m, 5H); ^{13}C NMR (CDCl_3) d 41.1, 41.8, 66.5, 70.0, 70.2, 70.4, 73.5, 127.9, 128.0, 128.4, 136.9, 156.4.

Compound 5 - [N-tert-butyloxycarbonyliminodiacetic acid]:
This compound was prepared by a procedure similar to that reported by Garrigues, B. and Lazraq, E.M. *Tetrahedron Letters* (1986) 27, 1685-1686. 47 mL (34.2 g, 338 mmol) of Et_3N was added to a stirred solution of 22.0 g (169 mmol) of iminodiacetic acid and 36.8 g (169 mmol) of di-tert butyldicarbonate in 169 mL of 50/50 dioxane/ H_2O at room temperature. The mixture was stirred for 24 hours and most of the dioxane was removed on a rotary evaporator. The mixture was partitioned between 350 mL of 1 N HCl and five 100 mL portions of EtOAc. The combined EtOAc layers were dried (MgSO_4), filtered, and concentrated to give a white solid. Recrystallization from hexanes/EtOAc yielded 35.3 g (90%) of compound 5 as crystals: m.p. 131-132° fused; ^1H NMR (DMSO) d 1.35 (s, 9H), 3.87 (s, 2H), 3.91 (s, 2H), 12.6 (bd s, 2H); ^{13}C NMR (DMSO) d 27.9, 49.6, 79.6, 154.8, 171.2.

Compound 6. 9.99 g (48.5 mmol) of dicyclohexylcarbodiimide was added to a solution of 4.52 g 73 (19.4 mmol) of compound 5 and 4.46 g (38.8

-47-

mmol) of N-hydroxysuccinimide in 100 mL of THF at 0°. The mixture was stirred for 3 hours at 0°C, and a solution of 5.39 mL (3.92 g, 38.8 mmol) Et₃N and 10.9 g (38.7 mmol) of compound 4 in 83 mL of THF was added, and the mixture was stirred at 5°C for 17 hours. The mixture was filtered to remove solids, and the filtrate was concentrated to an oil which was partitioned between 400 mL of EtOAc and two 100 mL portions of 1 N HCl. The EtOAc layer was washed with three, 100 mL portions of 1 N Na₂CO₃, 100 mL of brine, dried (MgSO₄), filtered and concentrated to provide 14.2 g (96%) of compound 6 as a thick oil; ¹H NMR (CDCl₃) δ 1.41 (s, 9H), 3.30-3.70 (m, 24H), 3.70-3.90 (m, 4H), 5.10 (s, 4H), 5.50 (bd s, 2H), 7.12 (bd s, 1H), 7.30-7.40 (m, 10H), 8.24 (bd s, 1H).

Compound 7. 26.3 mL (38.9 g, 156 mmol) of trifluoroacetic acid was added to a solution of 14.2 g (18.6 mmol) of compound 6 in 111 mL of CH₂Cl₂ and the mixture was stirred at room temperature for 3 hours. The mixture was concentrated on the rotary evaporator to give a viscous oil, and the oil was dissolved in 93 mL of THF. The solution was cooled to 0°C and 3.72 g (37.2 mmol) of succinic anhydride was added followed by 5.18 mL (3.76 g, 37.2 mmol) of Et₃N. The cooling bath was removed, and the mixture was stirred for 18 hours at room temperature. The solvent was removed under reduced pressure, and the resulting oil was partitioned between 300 mL of CH₂Cl₂ and three 100 mL portions of H₂O. The CH₂Cl₂ layer was dried (MgSO₄), filtered, and concentrated to provide an oil which was purified by chromatography on silica gel (9/1/0.1 EtOAc/MeOH/acetic acid) to provide 10.5 g (74%) of compound 7 as a viscous oil; ¹H NMR (CDCl₃) δ 2.50-2.60

-48-

(m, 4H), 3.30-3.60 (m, 24H), 3.88 (s, 2H), 4.03 (s, 2H),
5.07 (s, 4H), 5.77 (bd s, 2H), 7.20-7.30 (m 10H), 7.91
(bd s, 2H), 8.88 (bd s, 1H); ¹³C (CDCl₃) d 27.7, 29.0,
39.4, 41.0, 52.9, 53.8, 66.5, 69.3, 69.8, 70.0, 70.1,
127.8, 128.1, 128.3, 136.7, 156.6, 169.1, 169.6, 173.3,
174.5.

Compound 8 - [4-Nitrophenyl ester of compound 7]: 1.61 g
(7.83 mmol) of dicyclohexylcarbodiimide was added to a
solution of 3.98 g (5.22 mmol) of 7 and 800 mg
(5.75 mmol) of 4-nitrophenol in 26 mL of CH₂Cl₂ at 0°.
The mixture was stirred at room temperature under N₂ for
64 hours. The mixture was cooled to 0°, 1 mL of HOAc was
added, and the mixture was kept at 0° for 2 hours. The
solids were removed by filtration, and the filtrate was
concentrated. The residue was purified by silica gel
chromatography (gradient, 91/8/1 to 84/15/1
CH₂Cl₂/IPA/HOAc) to provide 2.58 g (56%) of compound 8 as
a viscous oil: ¹H NMR (CDCl₃) d 2.66 (t, 2H), 2.84 (t,
2H), 3.32-3.68 (m, 24H), 3.90 (bd s, 2H), 4.01 (bd s,
2H), 5.06 (s, 4H), 5.58 (bd m, 2H), 6.91 (bd m, 1H), 7.27
(d, 2H), 7.33 (s, 10H), 8.23 (d, 2H), 9.01 (bd m, 1H).

Compound 10 - [4-Nitrophenylbromoacetate]: 9.28 g
(45 mmol) of dicyclohexylcarbodiimide was added to a
stirred solution of 5.0 g (35.9 mmol) of bromoacetic acid
and 8.50 g (61.1 mmol) of 4-nitrophenol in 180 mL of
EtOAc at 0°. The mixture was stirred for 16 hours at 5°
and 1 mL of acetic acid was added. The mixture was
stirred for 20 minutes at room temperature and then
placed in a freezer for 20 minutes. The solid material
was removed by filtration, and the filtrate was
concentrated to a viscous oil and crystallized from

-49-

Et₂O/hexanes to provide 7.73 g (83%) of compound 10 as flakes: m.p. 86-87°; TLC R_f = 0.63 (50/50/1 hexanes/EtOAc/HOAc); ¹H NMR (CDCl₃) δ 4.13 (s, 2H), 7.36 (d, J=12 Hz, 2H), 8.32 (d, J=12 Hz, 2H); ¹³C NMR (CDCl₃) δ 24.9, 122.1, 125.3, 155.5, 164.9; Anal. calc'd for C₈H₆BrNO₄: C, 36.95; H, 2.33; N, 5.39. Found: C, 37.24; H, 2.33; N, 5.42.

Compound 9: 300 mg (3.57 mmol) of NaHCO₃, followed by 162 mg (1.09 mmol) of 2,2'-(ethylenedioxy)-diethylamine (Fluka), was added to a solution of 2.37 g (2.68 mmol) of compound 8 in 15 mL of dioxane and 8 mL of H₂O. The mixture was stirred for 24 hours at room temperature and concentrated under vacuum to approximately one half the original volume. The concentrate was partitioned between 40 mL of CH₂Cl₂ and 40 mL of saturated NaHCO₃ solution. The CH₂Cl₂ layer was then washed twice with 40 mL of 0.5 N HCl. The CH₂Cl₂ layer was washed with saturated NaCl solution, dried (MgSO₄), filtered, and concentrated to give 2.8 g of an oil. This crude produce was purified by silica gel chromatography (3/6/1 CH₂Cl₂/THF/MeOH) to provide 940 mg (59%) of compound 9 as an oil: TLC R_f = 0.21 (3/6/1 CH₂Cl₂/THF/MeOH); ¹H NMR (CDCl₃) δ 2.45 (m, 4H), 2.59 (m, 4H), 3.25-3.55 (m, 60H), 3.87 (s, 4H), 4.05 (s, 4H), 5.07 (s, 8H), 5.62 (bd s, 4H), 6.78 (bd s, 2H), 7.34 (bd s, 20H), 8.56 (bd s, 2H); ¹³C NMR (CDCl₃) δ 28.1, 30.3, 31.1, 39.4, 41.1, 52.9, 53.9, 66.5, 69.4, 69.7, 69.9, 70.2, 125.3, 127.8, 128.3, 136.8, 156.5, 168.8, 169.4, 172.1, 173.5.

Compound 34: 110 mg of 10% Pd on carbon was added to a solution of 281 mg (0.175 mmol) of compound 9 in 5 mL of

-50-

EtOH and 2 mL of cyclohexene under nitrogen and the resulting mixture was refluxed under nitrogen for 2 hours. When cool, the mixture was filtered through diatomaceous earth and concentrated under vacuum to give 170 mg (92%) of compound 34 as an oil which was used directly in the next step without purification; ¹H NMR (CDCl₃) δ 2.45 (m, 4H), 2.53 (m, 4H), 2.62 (m, 4H), 2.86 (m, 8H), 3.42-3.60 (m, 52H), 4.00 (s, 4H), 4.14 (s, 4H); ¹³C NMR (CDCl₃) δ 28.2, 30.3, 31.1, 39.4, 41.1, 46.5, 48.6, 52.9, 53.8, 69.4, 69.7, 70.2, 72.4, 168.9, 169.5, 172.3, 173.8.

Compound 11: 128 mg (1.4 mmol) of NaHCO₃ and 200 mg (0.85 mmol) of compound 10 were added to a solution of 165 mg (0.155 mmol) of compound 34 in 6 mL of dioxane and 3 mL of H₂O. The resulting mixture was stirred for 24 hours at room temperature and concentrated under vacuum. The concentrate was purified by chromatography on Sephadex® G-10 (MeOH) to give 114 mg (46%) of compound 11 as a viscous oil. An analytical sample was prepared by preparative HPLC (C₁₈; gradient 15/85/0.1 to 30/70/0.1 CH₃CN/H₂O/CF₃CO₂H, 50 min, 225 nm): ¹H NMR (CDCl₃) δ 2.58 (m, 4H), 2.65 (m, 4H), 3.43-3.62 (m, 60H), 3.92, (s, 8H), 4.03 (s, 4H), 4.16 (s, 4H); MS (FAB) m/e (relative intensity) MNa⁺ 1605 (100), MH⁺ 1579 (1), 1581 (5), 1583 (7), 1585 (6), 1587 (2).

Compound 12 - [Mono-N-carbobenzyloxy-1,6-diaminohexane]: A solution of 21 mL (25.7 g, 150 mmol) of benzylchloroformate in 200 mL of dioxane was added dropwise to a stirred solution of 17.49 g (150 mmol) of 1,6-hexanediamine and 19.58 g (196 mmol) of KHCO₃ in 100

-51-

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mL of dioxane and 300 mL of H₂O at 0°. The mixture was stirred at room temperature for 18 hours and then cooled to 0°. The mixture was acidified with 12 N HCl and extracted with two 100 mL portions of Et₂O. The aqueous layer was neutralized with 10 N NaOH and extracted with eight 100 mL portions of Et₂O. The basic extracts were combined, dried (Na₂SO₄), and concentrated to provide 5.03 g (13%) of crude compound 12 as a semisolid residue: ¹H NMR (DMSO) δ 1.22-1.51 (m, 8H), 2.54 (t, 2H), 3.02 (d of t, 2H), 5.05 (s, 2H), 7.30-7.48 (m, 5H).

Compound 13: 918 mg (4.45 mmol) of dicyclohexylcarbodiimide was added to a solution of 417 mg (1.78 mmol) of compound 5 and 409 mg (3.56 mmol) of NHS in 15 mL of THF at 0°. The mixture was stirred at 0° for 4.5 hours and a solution of 1.02 g (4.08 mmol) of compound 12 in 4 mL of THF was added. The mixture was stirred under N₂ at 5° for 18 hours. The concentrate was partitioned between 30 mL of EtOAc and two 30 mL portions of 1 N HCl. The combined EtOAc layers were washed successively with 30 mL of H₂O and 30 mL of saturated NaHCO₃ solution, dried (MgSO₄), filtered, and concentrated to provide 1.48 g of viscous residue. Purification by chromatography on silica gel (5/95 MeOH/CH₂Cl₂) gave 1.04 g (84%) of compound 13 as a sticky solid: ¹H NMR (CDCl₃) δ 1.33 (m, 8H), 1.43 (s, 9H), 1.51 (m, 8H), 3.18 (m, 4H), 3.26 (m, 4H), 3.81 (s, 2H), 3.85 (s, 2H), 4.90 (bd s, 2H), 5.10 (s, 4H), 6.81 (bd s, 1H), 7.28-7.40 (m, 10H), 8.05 (bd s, 1H).

Compound 14: 14.9 mL of trifluoroacetic acid was added to a solution of 5.16 g (7.45 mmol) of compound 13 in

-52-

14.9 mL of CH_2Cl_2 and the resulting mixture was stirred for 3 hours at room temperature. The mixture was concentrated under vacuum and redissolved in 57 mL of THF. 2.07 mL (1.51 g, 14.9 mmol) of Et_3N was added to the mixture. 1.5 g (14.9 mmol) of succinic anhydride was added to the mixture and the mixture was then stirred for 18 hours. The mixture was partitioned between 75 mL of 1 N HCl and four 75 mL portions of CH_2Cl_2 . The combined CH_2Cl_2 layers were dried (MgSO_4), filtered, and concentrated to provide a solid. Crystallization from $\text{CH}_2\text{Cl}_2/\text{EtOAc}/\text{hexanes}$ provided 3.84 g (74%) of compound 14 as a white solid: m.p. 122° ; ^1H NMR (MeOH) δ 1.32 (m, 8H), 1.48 (m, 8H), 2.56 (m, 4H), 3.10 (t, 4H), 3.23 (m, 4H), 4.00 (s, 2H), 4.18 (s, 2H), 5.05 (s, 4H), 7.33 (m, 10H).

Compound 15 - [4-Nitrophenyl ester of compound 14]:

887 mg (4.30 mmol) of dicyclohexylcarbodiimide was added to a solution of 2.0 g (2.87 mmol) of compound 14 and 438 mg (3.15 mmol) of 4-nitrophenol in 15 mL of THF at 0° . The mixture was allowed to come to room temperature, stirred for 18 hours, and then cooled to 0° . 200 μL of acetic acid was then added and the mixture was stirred at 0° for 1 hour. The solids were removed by filtration and the filtrate was concentrated to an oil. Purification by chromatography on silica gel (92/8 $\text{CH}_2\text{Cl}_2/\text{IPA}$) and recrystallization of the resulting solid from $\text{CH}_2\text{Cl}_2/\text{hexanes}$ provided 1.52 g (64%) of compound 15 as a white solid: m.p. $65-68^\circ$; ^1H NMR (CDCl_3) δ 1.30 (m, 8H), 1.47 (m, 8H), 2.71 (t, 2H), 2.90 (t, 2H), 3.17 (m, 4H), 3.25 (m, 4H), 3.92 (s, 2H), 4.08 (s, 2H), 4.86 (bd t, 1H), 4.95 (bd t, 1H), 5.09 (s, 4H), 6.28 (bd t, 1H), 7.23

-53-

(d, J=9 Hz, 2H), 7.32 (m, 10H), 8.22 (d, J=9 Hz, 2H),
8.95 (bd t, 1H).

5 Compound 16: A solution of 830 mg (0.99 mmol) of
compound 15 in 7.5 mL of dioxane was added to a solution
of 58 uL (59 mg, 0.40 mmol) of 2,2'-(ethylenedioxy)-
diethylamine (Fluka) and 111 mg (1.31 mmol) of NaHCO₃ in
7.5 mL of H₂O. The mixture was stirred at room
10 temperature for 18 hours. The mixture was partitioned
between 50 mL of 1 N HCl and 50 mL of CH₂Cl₂. The CH₂Cl₂
layer was dried (Na₂SO₄), filtered, and concentrated to
provide 1.28 g of viscous oil. Purification by silica
gel chromatography (84/15/1 CH₂Cl₂/MeOH/HOAc) gave 670 mg
15 of compound 16 as a waxy solid: ¹H NMR (CDCl₃) d 1.32 (m,
16H), 1.49 (m, 16H), 2.46 (m, 4H), 2.58 (m, 4H), 3.10-
3.23 (m, 16H), 3.34 (m, 4H) 3.48 (m, 4H), 3.53 (s, 4H),
3.85 (s, 4H), 4.02 (s, 4H), 5.05 (s, 8H), 5.07
(underlying bd t, 2H), 5.15 (bd t, 2H), 7.30 (m, 20H),
20 7.40 (bd t, 2H), 8.60 (bd t, 2H).

Compound 35: A solution of 613 mg (0.41 mmol) of
compound 16 in 20.3 mL of EtOH and 10.1 mL of cyclohexene
was stirred and purged with nitrogen. 20 mg of 10% Pd on
25 carbon (Aldrich) was added and the mixture was heated in
a 85° oil bath for 1.5 hours. When cool, the mixture was
filtered through diatomaceous earth using 50/50
H₂O/acetone to rinse the flask and filter. The filtrate
was concentrated under vacuum to give 448 mg (114%) of
30 compound 35 as a waxy solid: ¹H NMR (D₂O) d 1.39 (m, 16H),
1.59 (m, 16H), 2.57 (t, 4H), 2.65 (t, 4H), 2.88 (t, 8H),
3.23 (t, 4H), 3.29 (t, 4H), 3.42 (t, 4H), 3.65 (t, 4H),
3.71 (s, 4H), 4.06 (s, 4H), 4.30 (s, 4H).

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-54-

Compound 17: 546 mg (6.50 mmol) of NaHCO₃ was added to a solution of 445 mg (0.406 mmol) of compound 35 in 9.5 mL of H₂O. A solution of 838 mg (3.25 mmol) of compound 10 in 14.4 mL of dioxane was added to the resulting mixture. The mixture was stirred for 7 hours at room temperature and partitioned between 50 mL of 0.1 N H₂SO₄ and 50 mL of CH₂Cl₂. The CH₂Cl₂ layer was discarded, and the aqueous layer was extracted with two 50 mL portions of CH₂Cl₂, two 50 mL portions of 9/1 CH₂Cl₂/MeOH, 50 mL of 4/1 CH₂Cl₂/MeOH, and 50 mL of 3/2 CH₂Cl₂/MeOH. The extracts were combined and dried (Na₂SO₄), filtered, and concentrated to provide 282 mg of solid. Crystallization from EtOH/EtOAc/Et₂O gave 143 mg (24%) of compound 17 as a white solid: ¹H NMR (CDCl₃/MeOH) δ 1.33 (m, 16H), 1.55 (m, 16H), 2.55 (m, 8H), 3.21 (m, 16H), 3.39 (m, 4H), 3.55 (m, 4H), 3.81 (s, 8H), 3.95 (s, 4H), 4.12 (s, 4H). Anal. calc'd for C₃₄H₄₄N₁₂O₁₄Br₄: C, 44.57; H, 6.51; N, 11.55; Br, 21.97. Found: C, 45.85; H, 6.49; N, 11.37; Br, 19.90.

Compound 18 - [1,5-Bis(N-carbobenzyloxy-6-aminohexanoamido)-3-azapentane]: 3.09 g (19.0 mmol) of carbonyldiimidazole was added to a solution of 5.05 g (19.0 mmol) of N-carbobenzyloxy-6-aminohexanoic acid in 25 mL of EtOAc at room temperature. The mixture was stirred for 15 hours and 1.02 mL (982 mg, 9.52 mmol) of diethylenetriamine was then added followed by 2.65 mL (1.93 g, 19.0 mmol) of Et₃N. The resulting mixture was stirred for 4 hours, and the solid product was collected by filtration. Recrystallization (MeOH/EtOAc) gave 4.27 g (75%) of compound 18 as a fine grainy solid: m.p. 132-133°; ¹H NMR (CDCl₃) δ 1.33 (m, 4H), 1.52 (m, 4H), 1.64 (m, 4H), 2.18 (t, 4H), 2.73 (t, 4H), 3.16 (m, 4H), 3.35 (m, 4H), 4.96 (bd s, 2H), 5.09 (s, 4H), 6.13 (bd s,

-55-

2H), 7.33 (s, 10H); Anal. calc'd for $C_{32}H_{47}N_3O_6$: C, 64.29; H, 7.50; N, 11.72. Found: C, 63.54; H, 7.75; N, 11.91.

5 Compound 19: 657 uL (880 mg, 3.2 mmol) of triethyleneglycol-bis-chloroformate (Aldrich) was added to a solution of 4.86 g (8.1 mmol) of compound 18 in 162 mL of pyridine in a 20° water bath. The mixture immediately formed a precipitate. The mixture was
10 stirred for 16 hours and the resulting cloudy yellow solution was concentrated under vacuum. The concentrate was partitioned between 150 mL of EtOAc and two 150 mL portions of 1 N HCl (making sure the aqueous layer was acidic). The aqueous layers were combined and extracted
15 with a second 150 mL portion of EtOAc. The EtOAc layers were combined, dried ($MgSO_4$), filtered, and concentrated. The resulting residue was crystallized (EtOAc/hexanes/ $CHCl_3$) to provide 1.92 g (43%) of compound 19 as fine yellow tinted crystals: m.p. 86-91°; 1H NMR ($CDCl_3$) 1.31 (m, 8H), 1.52 (m, 8H), 1.62 (m, 8H), 2.20 (m, 8H), 3.20 (m, 8H), 3.39 (s, 16H), 3.62 (s, 4H), 3.68 (m, 4H), 4.26 (m, 4H), 5.08 (s, 8H), 5.32 (bd s, 4H), 7.31 (bd s, 4H), 7.37 (s, 20H); ^{13}C NMR ($CDCl_3$) d 25.1, 26.2, 26.4, 29.6, 36.0, 36.2, 38.5, 38.8, 40.8, 64.5, 25 66.4, 69.1, 70.3, 128.0, 128.4, 136.7, 156.5, 156.9, 173.6; Anal. calc'd for $C_{72}H_{104}N_{10}O_{11}$: C, 61.87; H, 7.50; N, 10.02. Found: C, 61.68; H, 7.63; N, 9.95.

Compound 36: 3.5 mL of cyclohexene was added to a
30 solution of 800 mg (0.57 mmol) of compound 19 in 5 mL of absolute EtOH. The solution was placed under nitrogen, 500 mg of 10% Pd on carbon was added, and the resulting mixture was refluxed with stirring for 2 hours. When
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-56-

cool, the mixture was filtered through diatomaceous earth and concentrated to give 500 mg (100%) of compound 36 as an oil: ^1H NMR (50/50 $\text{CDCl}_3/\text{CD}_3\text{OD}$) δ 1.21 (m, 8H), 1.49 (m, 8H), 1.62 (m, 8H), 2.19 (t, $J = 7.4$ Hz, 8H), 2.67 (t, $J = 7.4$ Hz, 8H), 3.36 (bd s, 16H), 3.67 (s, 4H), 3.71 (m, 4H), 4.21 (m, 4H).

Compound 20: 3.9 g (46.4 mmol) of NaHCO_3 was added to a solution of 5.0 g (5.8 mmol) of compound 36 in 37.5 mL of dioxane and 12.5 mL of H_2O . The mixture was cooled to 0° in an ice bath and 8.7 g (34.8 mmol) of 4-nitrophenylbromoacetate, compound 10, was added. The mixture was stirred at 0° for 1 hour and 50 mL of 1 N H_2SO_4 was slowly added. The mixture was extracted with three, 50 mL portions of EtOAc. The EtOAc extracts were discarded and the aqueous layer was extracted with six, 50 mL portions of 20/80 MeOH/ CH_2Cl_2 . The combined MeOH/ CH_2Cl_2 layers were dried (Na_2SO_4), filtered, and concentrated. The residue was purified by silica gel chromatography (step gradient 9/1 $\text{CH}_2\text{Cl}_2/\text{MeOH}$ then 85/15/5 $\text{CH}_2\text{Cl}_2/\text{MeOH}/\text{THF}$) to provide 3.62 g (46%) of compound 20 as a white solid: melting point $66.0\text{--}70.5^\circ$. An analytical sample was prepared by preparative HPLC (C_{18} reversed phase column, gradient 25/75/0.1 to 35/65/0.1 $\text{CH}_3\text{CN}/\text{H}_2\text{O}/\text{CF}_3\text{CO}_2\text{H}$ over 50 minutes, 225 nm) to give a clear oil which solidified on standing under vacuum to give a white solid: melting point $87\text{--}89^\circ$; ^1H NMR (CDCl_3) δ 1.35 (m, 8H), 1.55 (m, 8H), 1.64 (m, 8H), 2.26 (m, 8H), 3.28 (m, 8H), 3.42 (bd s, 16H), 3.66 (s, 4H), 3.70 (m, 4H), 3.89 (s, 8H), 4.19 (m, 4H); ^{13}C NMR (CDCl_3) δ 25.1, 26.2, 28.8, 29.0, 38.5, 39.1, 40.0, 47.8, 48.3, 64.7, 69.1, 70.3, 157.0, 166.3, 174.9; MS (FAB) m/e (relative

-57-

intensity) MH⁺ [1341(25), 1343(60), 1345(70), 1347(56),
1349(21)], 705.6(100); Anal. calc'd for C₄₈H₈₄N₁₀O₁₄Br₄: C,
42.86; H, 6.29; N, 9.27; Br, 23.77. Found: C, 42.15; H,
6.28; N, 9.87; Br, 25.33.

Compound 21 - [Tetrakis-(2-cyanoethoxymethyl) methane]:

This compound was prepared similarly to the method
reported (Bruson, H.A., U.S. Patent 2,401607; June 4,
1946). 27.3 mL (21.8 g, 411 mmol) of acrylonitrile was
added to a stirred solution of 8.0 g (58.8 mmol) of
pentaerythritol and 1.76 mL of a 40% aqueous solution of
benzyltrimethylammonium hydroxide in 50 mL of H₂O. A
reflux condenser was affixed and the mixture was heated
under N₂ atmosphere with stirring at 40° for 16 hours and
then at 60° for 24 hours. When cool, the mixture was
acidified with 1 mL of concentrated HCl and transferred
to a separatory funnel. The oil which settled to the
bottom was collected, and the aqueous phase was extracted
with three 40 mL portions of CH₂Cl₂. The oil and combined
extracts were dried (MgSO₄), filtered, and concentrated
to give 23.5 g of oil. Biscyanoethyl ether was removed
by Kugelrohr distillation at 110° and 0.25 torr. The
pot residue was crystallized from 1 L of H₂O to give 8.43
g (41%) of compound 21 as white needles: m.p. 42.5°
[Reported (Macromolecules 1991, 24, 1443-1444.) 39-40°];
¹H NMR (CDCl₃) δ 2.61 (t, J = 6 Hz, 8H), 3.50 (s, 8H), 3.6
(t, J = 6 Hz, 8H).

Compound 22 - [Tetrakis-(2-carboxyethoxymethyl) methane]:

A solution of 5.0 g (14.35 mmol) of compound 21 in
21.5 mL of concentrated HCl was stirred at 75° for 3 h;
during this time a white precipitate formed. The aqueous

-58-

HCl was removed under vacuum, and the mixture was concentrated twice from 25 mL of H₂O. The resulting 9.68 g of solid material was loaded onto a 45 mm i.d. column containing a 16.5 cm bed of DOW-1-X2 resin in the hydroxide form, and the column was eluted with 200 mL of H₂O followed by 1 N HCl. Fractions containing product, as evidenced by TLC (80/20/1 CH₃CN/H₂O/HOAc), were concentrated to give 1.21 g (21%) of 22 as an oil: ¹H NMR (D₂O) δ 2.46 (t, J = 6 Hz, 8H), 3.22 (s, 8H), 3.55 (t, J = 6 Hz, 8H).

Compound 23: 3.71 mL (6.06 g, 50.8 mmol) of thionyl chloride was added to a solution of 1.12 g (2.85 mmol) of compound 22 in 7.0 mL of THF. The mixture was stirred at room temperature for 3 hours and the solvents were removed under vacuum. The crude acid chloride was dissolved in 7 mL of THF. 2.12 mL (1.54 g, 15.24 mmol) of Et₃N was then added to the solution. The mixture was stirred under N₂ and cooled to 0°. A solution of 3.60 g (12.74 mmol) of compound 4 in 5 mL of THF was added over a 1 minute period. The cooling bath was removed, and the mixture was stirred for 5.5 hours at room temperature and then partitioned between 25 mL of 1 N HCl and four 25 mL portions of EtOAc. The EtOAc layers were combined, washed with brine, dried (MgSO₄), filtered, and concentrated to provide 3.46 g of viscous oil. Purification by chromatography on silica gel (95/5 CH₂Cl₂/MeOH) provided 1.26 g (30%) of compound 23 as a viscous oil: ¹H NMR (CDCl₃) δ 2.40 (t, 8H), 3.29 (s, 8H), 3.35 (m, 16H), 3.48-3.77 (m, 48H), 5.12 (s, 8H), 5.60 (bd, 4H), 6.85 (bd, 4H), 7.34 (s, 20H).

-59-

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5 Compound 37: 4.0 mL of cyclohexene and 83 mg of 10% Pd
on carbon were added to a solution of 142 mg (0.093 mmol)
of compound 23 in 8.4 mL of EtOH under N₂. The mixture
was refluxed with stirring in a 90° oil bath for 3 hours
and, when cool, filtered through diatomaceous earth using
CH₂Cl₂ to wash the filter and flask. The filtrate was
concentrated to provide 70 mg (78%) of compound 37 as an
oil: ¹H NMR (CDCl₃) δ 2.90 (t, 8H), 3.33 (s, 8H), 3.45
10 (t, 8H), 3.52-3.73 (m, 48H).

15 Compound 24: 40 mg (0.48 mmol) of NaHCO₃ and 104 mg
(0.40 mmol) of compound 10 were added to a solution of
70 mg (0.098 mmol) of compound 37 in 2 mL of dioxane and
0.67 mL of H₂O. The mixture was stirred for 17 hours at
room temperature and 0.5 mL of 1 N H₂SO₄ was added,
bringing the pH to 4. The mixture was concentrated, and
the concentrate was purified by chromatography on G-10
Sephadex® (MeOH). The fractions containing product were
20 concentrated under vacuum to provide 91 mg of oil.
Purification of 36 mg of the crude product by HPLC (C₁₈,
gradient 20/80/0.1 to 35/65/0.1 CH₃CN/H₂O/CF₃CO₂H) gave
19 mg (44%) of compound 24 as an oil: ¹H NMR (CDCl₃) δ
2.50 (t, 8H), 3.31 (s, 8H), 3.36-3.72 (m, 56H), 3.91 (s,
25 8H); ¹³C NMR (CDCl₃) δ 28.8, 36.5, 39.7, 40.0, 67.2, 69.3,
69.5, 70.3, 166.6, 173.0. MS(FAB) m/e (relative
intensity) MH⁺ [1425(15), 1427(63), 1429(75), 1431(64),
1433(12)], 577(100).

30 Compound 25a - [Bis-tolsylate of PEG₃₃₅₀]: 6.47 mL of
pyridine was added to a solution of 16.75 g (5.0 mmol) of
polyethylene glycol (J.T. Baker, average molecular weight
3350 g per mol) which had been dried by azeotropic
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-60-

distillation (toluene) in 40 mL of CH_2Cl_2 . The solution was placed under nitrogen and cooled to 0° . A solution of 7.63 g (40 mmol) of tosyl chloride in 40 mL of CH_2Cl_2 was added over a 25 minute period. The cooling bath was removed and the mixture was stirred at room temperature for 16 hours. The mixture was shaken with 80 mL of 1 N HCl and the CH_2Cl_2 layer which contained emulsions was washed with 100 mL of H_2O . The CH_2Cl_2 layer was dried (MgSO_4), filtered, and concentrated. The residue was crystallized from $\text{CH}_2\text{Cl}_2/\text{Et}_2\text{O}$ to provide 16.82 g (92%) of compound 25a as a white solid: ^1H NMR (CDCl_3) δ 2.50 (s, 6H), 3.48 (t, $J = 5$ Hz, 4H), 3.55-3.77 (m, more than 600H, integral too large to be accurate), 3.83 (t, $J = 5$ Hz, 4H), 7.44 (d, $J = 7$ Hz, 4H), 7.94 (d, $J = 7$ Hz, 4H).

Compound 26a - Diazido-PEG₃₃₅₀: A solution of 10.83 g (2.96 mmol) of compound 25a and 1.92 g (29.6 mmol) of NaN_3 in 30 mL of DMF was heated under N_2 in a 120° oil bath for 3 hours. When cool, the mixture was partitioned between 100 mL of H_2O and 100 mL of CH_2Cl_2 . The CH_2Cl_2 layer was diluted to 200 mL with CH_2Cl_2 and washed with 100 mL of 1 N HCl, dried (Na_2SO_4), filtered and concentrated. The resulting waxy solid was recrystallized ($\text{CH}_2\text{Cl}_2/\text{Et}_2\text{O}$), and the resulting solids were further purified by chromatography on silica gel (gradient 98/2 to 95/5 $\text{CH}_2\text{Cl}_2/\text{MeOH}$) to provide 4.75 g (47%) of compound 26a as a waxy solid: TLC Rf 0.41 (9/1 CH_2Cl_2); ^1H NMR (CDCl_3) δ 3.35 (t, $J = 5$ Hz, 4H), 3.44 (t, $J = 5$ Hz, 2H), 3.54-3.77 (m, approx. 300H, integral too large to be accurate), 3.79 (t, $J = 5$ Hz, 2H).

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-61-

Compound 27a - [Diamino-PEG₃₃₅₀]: 473 mg of 10% Pd on carbon (Aldrich) was added to a solution of 4.75 g (1.39 mmol) of compound 26a in 140 mL of EtOH. The mixture was shaken under 60 psi of H₂ for 30 hours. Because the reaction was incomplete (TLC, 9/1 CH₂Cl₂/MeOH), another 473 mg of 10% Pd on carbon was added and the mixture was shaken under 60 psi of H₂ for another 5 hours. The mixture was then filtered through diatomaceous earth, concentrated under vacuum, and the concentrate was crystallized (CH₂Cl₂/Et₂O) to give 4.03 g (86%) of compound 27a as a white solid: ¹H NMR (CDCl₃) δ 2.92 (t, 4H), 3.49 (t, 2H), 3.66 (t, 4H), 3.67 (m, approx. 300H, integral too large to be accurate), 3.86 (t, 2H).

Compound 28 - [N-hydroxysuccinimidyl ester of compound 7]: 596 mg (2.89 mmol) of dicyclohexylcarbodiimide was added to a solution of 1.84 g (2.41 mmol) of compound 7 and 278 mg (2.41 mmol) of NHS in 12 mL of THF at 0° under N₂. The cooling bath was removed, and the mixture was stirred at room temperature for 16 hours. 250 uL of acetic acid was added to the mixture. Stirring was continued at room temperature for 1 hour. The mixture was then placed in a freezer for 2 hours. The solids were removed by filtration, and the filtrate was concentrated to give 2.27 g (110%) of crude compound 28 as a viscous oil. Compound 28 was difficult to purify without decomposition, so it was used directly to acylate diamino-PEG.

Compound 29a: A solution of 900 mg (1.05 mmol) of compound 28 in 4.68 mL of dioxane was added to a solution of 877 mg (0.26 mmol) of compound 27a and 176 mg

-62-

(2.10 mmol) of NaHCO_3 in 3.12 mL of H_2O at 0° . The mixture was stirred for 2 hours and then partitioned between 25 mL of 1 N HCl and two 25 mL portions of CH_2Cl_2 . The combined CH_2Cl_2 layers were dried (Na_2SO_4), filtered, and concentrated to give a viscous oil. Purification by silica gel chromatography (gradient, 95/5 to 87/13 $\text{CH}_2\text{Cl}_2/\text{MeOH}$) yielded 695 mg (55%) of compound 29a as a waxy solid: ^1H NMR (CDCl_3) δ 2.55 (bd, 8H), 3.39 (m, 16H), 3.44-3.72 (m, approx. 432H, integral too large to be accurate), 3.89 (s, 4H), 4.03 (s, 4H), 5.09 (s, 8H), 7.36 (s, 20H).

Compound 38a: 7.1 mL of cyclohexene was added to a solution of 688 mg (0.142 mmol) of compound 29a in 14.2 mL of EtOH under N_2 . 284 mg of 10% Pd on carbon was added and the resulting mixture was refluxed for 2 hours. When cool, the mixture was filtered through diatomaceous earth with EtOH , and the filtrate was concentrated under vacuum to yield 550 mg (90%) of compound 38a as a waxy solid: ^1H NMR (CDCl_3) δ 2.58 (m, 8H), 2.93 (m, 8H), 3.38-3.76 (m, approx. 550H), 4.00 (s, 4H), 4.13, (s, 4H).

Compound 30a: A solution of 268 mg (1.04 mmol) of compound 10 in 4.65 mL of dioxane was added to a solution of 550 mg (0.13 mmol) of compound 38a and 175 mg (2.08 mmol) of NaHCO_3 in 3.11 mL of H_2O at 0° . The mixture was stirred for 20 hours and partitioned between 50 mL of 1 N H_2SO_4 and two 50 mL portions of CH_2Cl_2 . The combined CH_2Cl_2 layers were dried (Na_2SO_4), filtered, and concentrated to an oil. Purification by G-10 Sephadex® chromatography (MeOH) gave an amorphous solid which was crystallized ($\text{EtOH}/\text{Et}_2\text{O}$) to provide 378 mg (61%) of

-63-

compound 30a as a white solid: ^1H NMR (CDCl_3) δ 2.59 (bd s, 8H), 3.38-3.82 (m, approx. 500H, integral too large to be accurate), 3.88 (s, 8H), 3.98 (s, 4H), 4.10 (s, 4H);
5 bromoacetyl determination (European Journal of Biochemistry, 1984, 140, 63-71): Calculated, 0.84 mmol/g; Found, 0.50 mmol/g.

Compound 25b - [Bis-tosylate of PEG₈₀₀₀]: 2.3 mL

10 (16.5 mmol) of triethylamine, followed by 3.15 g (16.5 mmol) of TsCl , was added to a solution of 12.0 g (1.5 mmol) of PEG₈₀₀₀ (Aldrich, average molecular weight 8000 g/mmol) which had been dried by azeotropic distillation (toluene) in 30 mL of CH_2Cl_2 . The mixture
15 was stirred at room temperature for 18 hours and extracted with four, 50 mL portions of 1 N HCl followed by 50 mL of saturated NaCl solution. The CH_2Cl_2 layer was dried (Na_2SO_4), filtered, and concentrated under vacuum to provide a waxy solid. Recrystallization ($\text{CH}_2\text{Cl}_2/\text{Et}_2\text{O}$)
20 gave 11.0 g (92%) of compound 25b as a white solid: ^1H NMR (CDCl_3) δ 2.38 (s, 6H), 3.40-3.89 (m, approx. 800H, integral too large to be accurate), 4.14 (m, 4H), 7.34 (d, $J = 8.2$ Hz, 4H), 7.79 (d, $J = 8.2$ Hz, 4H).

25 Compound 26b - [Diazido-PEG₈₀₀₀]: 1.86 g (28.6 mmol) of NaN_3 was added to a solution of 10.8 g (1.3 mmol) of compound 25b in 30 mL of dry DMF. The mixture was heated under N_2 at 120° for 2.5 hours. When cool, the mixture was partitioned between 240 mL of CH_2Cl_2 and three 50 mL
30 portions of 0.5 N HCl. The CH_2Cl_2 layer was washed with 50 mL of saturated NaCl solution, dried (Na_2SO_4), filtered, and concentrated to give a solid. Purification by chromatography on silica gel (gradient 2/98 to 6/94
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-64-

MeOH/CH₂Cl₂) and recrystallization of the purified product
(MeOH/Et₂O) gave 6.95 (66%) of compound 26a as a white
solid: TLC (R_f = 0.33, 12/88 MeOH/CH₂Cl₂); ¹H NMR (CDCl₃)
5 3.39-3.86 (m).

Compound 27b - [Diamino-PEG₈₀₀₀]: A solution of 6.9 g
(0.86 mmol) of compound 26b in 150 mL of MeOH saturated
with ammonia was sparged with nitrogen. 1.5 g of 10%
10 Pd/C was added and the mixture was shaken under 65 psi of
H₂. After 20 hours, TLC analysis indicated that the
reaction was incomplete. As a result, 200 mg of 10% Pd/C
was added and shaking under 65 psi of H₂ was continued
for another 20 hours. The mixture was filtered through
15 diatomaceous earth and the filtrate was concentrated
under vacuum. The resulting waxy solid was
recrystallized (MeOH/Et₂O) to give 6.0 g (89%) of
compound 27b as a white solid. ¹H NMR (CDCl₃) δ 2.96 (t,
J = 5.1 Hz, 4H), 3.40-3.89 (m, approx. 700H, integral too
20 large to be accurate).

Compound 29b: 221 mg (2.63 mmol) of NaHCO₃ was added to
a solution of 3.0 g (0.375 mmol) of compound 27b in 10 mL
of water and 3 mL of dioxane. 1.3 g (1.51 mmol) of
25 compound 28 dissolved in 10 mL of dioxane was then added.
The mixture was stirred for 24 hours and then 40 mL of
0.5 N HCl was added. The mixture was extracted with
four, 25 mL portions of CH₂Cl₂. The combined CH₂Cl₂ layers
were dried (MgSO₄), filtered, and concentrated to an oil.
30 Crystallization from MeOH/Et₂O provided 2.0 g (58%) of
compound 29b: ¹H NMR (CDCl₃) δ 2.52 (m, 8H), 3.40-3.64 (m,
approx. 700H, integral too large to be accurate), 3.89
(s, 4H), 4.02 (s, 4H), 5.09 (s, 8H), 7.35 (s, 20H).
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-65-

Compound 38b: 123 mg of 10% Pd/C was added to a solution of 600 mg (0.063 mmol) of compound 29b in 5 mL of absolute EtOH and 2.5 mL of cyclohexene under nitrogen.

5 This mixture was refluxed under nitrogen for 2 hours. The reaction mixture was filtered through diatomaceous earth and evaporated to give 549 mg (97%) of compound 38b as a white solid: ¹H NMR (CDCl₃) δ 2.58 (m, 8H), 2.90 (m, 8H), 3.39-3.70 (m, approx. 700H, integral too large to be accurate), 4.05 (s, 4H), 4.15 (s, 4H).

10 Compound 30b: 100 mg (1.2 mmol) of NaHCO₃, followed by 84 mg (0.32 mmol) of compound 10, was added to a solution of 529 mg (0.059 mmol) of compound 38b in 2 mL of dioxane and 5 mL of water. After stirring for 12 hours, the reaction was acidified with 1 N H₂SO₄ and extracted with four, 40 mL of CHCl₃. The combined CHCl₃ layers were dried (MgSO₄), filtered, and concentrated to give 503 mg of semi-solid residue. The residue was purified by chromatography on G-10 Sephadex® (MeOH) and crystallized (MeOH/Et₂O/hexanes) to give 215 mg (39%) of compound 30b as a white solid: ¹H NMR (CDCl₃) δ 2.58 (m, 8H, 3.35-3.70 (m, approx. 700H, integral too large to be accurate), 3.89 (s, 8H), 4.01 (s, 4H), 4.16 (s, 4H); bromoacetyl determination (European Journal of Biochemistry 1984, 140, 63-71): Calculated, 0.42 mmol/g; Found, 0.27 mmol/g.

15 Compound 31 - [PEG₃₃₅₀-bis-chloroformate]: Two drops of dry pyridine, followed by 125 mg (0.418 mmol) of triphosgene, was added to a solution of 1.0 gram (0.249 mmol) of polyethylene glycol (J.T. Baker, average molecular weight 3350 g per mol) which had been dried by azeotropic distillation (toluene) in 12 mL of CH₂Cl₂. The

-66-

5 mixture was stirred at room temperature for 20 hours and the solvent was evaporated under vacuum to give 1.0 g (100%) of compound 31 as a white solid: ¹H NMR (CDCl₃) d 3.40-3.65 (m, approx. 300H, integral too large to be accurate), 3.77 (m, 4H), 4.46 (m, 4H).

10 Compound 32: A solution of 1.0 g (0.25 mmol) of compound 31 in 12 mL of 5:1 CH₂Cl₂/dioxane was added dropwise to a 50° solution of 600 mg (1.0 mmol) of compound 18 in 10 mL of dioxane and 1.5 mL of pyridine. The resulting cloudy solution was stirred for 72 hours. 25 mL of CH₂Cl₂ was added and the mixture was then filtered. The filtrate was evaporated and the semi-solid residue was purified by chromatography on G-10 Sephadex®. The resulting solid was crystallized (CH₂Cl₂/Et₂O) to give 829 mg (75%) of compound 32 as a faintly yellow solid: ¹H NMR (CDCl₃) d 1.30 (m, 8H), 1.40 (m, 8H), 1.61 (m, 8H), 2.18 (m, 8H), 3.17 (m, 8H), 3.40 (m, 16H), 3.62 (m, approx. 300H, integral too large to be accurate), 4.15 (m, 4H), 5.07 (s, 8H), 7.33 (m, 20H).

25 Compound 39: 100 mg of 10% Pd/C was added to a solution of 300 mg (0.065 mmol) of compound 32 in 5 mL of absolute EtOH and 2 mL of cyclohexene under nitrogen. This mixture was refluxed under nitrogen for 2 hours. The mixture was filtered through diatomaceous earth and the solvent was evaporated to give 237 mg (90%) of compound 39 as a white solid: ¹H NMR (CDCl₃) d 1.37 (m, 8H), 1.48 (m, 8H), 1.65 (m, 8H), 2.21 (m, 8H), 2.50 (m, 8H), 3.39 (m, 16H), 3.64 (m, approx. 300H, integral too large to be accurate), 4.19 (m, 4H).

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-68-

compound 40 as a yellow-brown solid: ^1H NMR (CDCl_3) δ 4.00 (s, 2H), 7.39 (d, 2H), 8.40 (m, 2H).

5 Compound 41: 103 mg (1.22 mmol) of NaHCO_3 , followed by
211 mg (0.692 mmol) of compound 40, was added to a
solution of 110 mg (0.104 mmol) of compound 34 in 5 mL of
dioxane and 5 mL of H_2O . The mixture was stirred for 18
10 hours and then concentrated under vacuum. Purification
by chromatography on Sephadex® (MeOH) provided 140 mg
(87%) of compound 41 as an oil. An analytical sample was
prepared by preparative HPLC (C_{18} , gradient 20/80/0.1 to
25/75/0.1 $\text{CH}_3\text{CN}/\text{H}_2\text{O}/\text{TFA}$ over 60 minutes, 225 nm): ^1H NMR
(CDCl_3) δ 2.59 (m, 4H), 2.65 (m, 4H), 3.44-3.62 (m, 60H),
15 3.77 (s, 4H), 3.78 (s, 4H), 4.02 (s, 4H), 4.21 (s, 4H).

Compound 42: 145 mg (0.935 mmol) of N-
methoxycarbonylmaleimide was added with vigorous stirring
to a solution of 171 mg (0.161 mmol) of compound 34 in
20 8 mL of dioxane, 2 mL of saturated NaHCO_3 solution, and
2 mL of H_2O at 0° (The Practice of Peptide Synthesis, M.
Bodansky and A. Bodansky, Springer-Verlag, New York,
1984, pages 29-31. Keller, O., Rudinger, J. Helv. Chim.
Acta 1975, 58, 531.). After 15 minutes, 25 mL of dioxane
25 was added, the cooling bath was removed, and stirring was
continued for 45 minutes at room temperature. The
mixture was extracted with two, 30 mL portions of CHCl_3 ,
and the combined CHCl_3 layers were dried (MgSO_4),
filtered, and concentrated to an oil. Purification by
30 chromatography on G-10 Sephadex® (MeOH) gave 103 mg (45%)
of compound 42 as an oil. An analytical sample was
prepared by preparative HPLC (C_{18} , gradient 20/80/0.1 to
25/75/0.1 $\text{CH}_3\text{CN}/\text{H}_2\text{O}/\text{TFA}$ over 65 minutes, 225 nm) to give
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-69-

an oil: ^1H NMR (CDCl_3) δ 2.57 (m, 4H), 2.67 (m, 4H), 3.42-3.65 (m, 52H), 3.72 (m, 8H), 4.03 (s, 4H), 4.17 (s, 4H), 6.74 (s, 4H), 6.75 (s, 4H).

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Compound 43 - [hydroxymethyl-tris-(2-cyanoethoxymethyl)methane]: 0.30 g (5.41 mmol) of KOH, followed by 23 mL (18.6 g, 350 mmol) of acrylonitrile, was added to a solution of 6.8 g (50 mmol) of pentaerythritol in 50 mL of H_2O . The mixture was stirred at room temperature for 16 hours, acidified with 1.5 mL of concentrated HCl solution, and extracted with two, 50 mL portions of CH_2Cl_2 . The combined CH_2Cl_2 layers were dried (MgSO_4), filtered, and concentrated to give 16.97 g of liquid. Purification by chromatography on silica gel (EtOAc) yielded 8.49 g (51%) of compound 43 as a viscous oil: TLC, R_f = 0.15 (EtOAc); ^1H NMR (CDCl_3) δ 2.62 (t, 6H), 3.54 (s, 6H), 3.68 (t, 6H), 3.70 (s, 2H).

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Compound 44 - [hydroxymethyl-tris-(2-carboxymethylethoxymethyl)methane]: 78 mL of a saturated solution of HCl in MeOH was added to 5.45 g (15.6 mmol) of compound 43. The mixture was heated at reflux for 1 hour and, when cool, partitioned between 100 mL of H_2O and four, 100 mL portions of Et_2O . The combined Et_2O layers were washed successively with 100 mL of saturated NaHCO_3 solution and 100 mL of saturated NaCl solution, dried (MgSO_4), filtered, and concentrated to yield 4.74 g of viscous liquid. Purification by chromatography on silica gel provided 3.05 g (50%) of compound 44 as an oil: TLC, R_f = 0.27 (80/20 EtOAc/hexanes); ^1H NMR (CDCl_3) δ 2.58 (t, 6H), 3.43 (s, 6H), 3.61 (s, 2H), 3.69 (t, 6H), 3.70 (s, 9H); ^{13}C NMR (CDCl_3) δ 34.8, 44.9, 51.6, 65.2, 66.9, 71.0, 172.1.

-70-

Compound 45: A mixture of 560 mg (1.4 mmol) of compound 44 and 1.69 g (6.0 mmol) of compound 4 was heated under nitrogen at 150° for 4 hours. The mixture was partitioned between 50 mL of EtOAc and 25 mL of 1N HCl, and the HCl layer was extracted with 25 mL of saturated NaHCO₃ solution, dried (K₂CO₃), filtered, and concentrated to a viscous residue. Purification by chromatography on silica gel (gradient 95/5 to 90/10 CH₂Cl₂/MeOH) provided 300 mg (19%) of compound 45 as a viscous oil: TLC, R_f = 0.24 (90/10 CH₂Cl₂); ¹H NMR (CDCl₃) δ 2.40 (t, 6H), 3.38 (s, 6H), 3.39-3.48 (m, 12H), 3.52-3.67 (m, 32H), 5.13 (s, 6H), 5.62 (bd s, 3H), 6.80 (bd s, 3H), 7.40 (s, 15H).

Compound 46: 104 mg of 10% Pd/C was added to a solution of 308 mg (0.269 mmol) of compound 45 in 10.4 mL of EtOH and 5.2 mL of cyclohexene under nitrogen. A reflux condenser was attached and the mixture was heated in an 85° oil bath for 1.5 hours. When cool, the mixture was filtered through diatomaceous earth and the filtrate was concentrated to provide 177 mg of residue. The residue was partially dissolved in 5.98 mL of dioxane. The resulting mixture was added to 386 mg (1.49 mmol) of compound 10 followed by a solution of 251 mg (2.99 mmol) of NaHCO₃ in 3.99 mL of H₂O. The resulting mixture was stirred under nitrogen for 18 hours and partitioned between 25 mL of 1N HCl and three 25 mL portions of CH₂Cl₂. The aqueous phase was extracted with three 25 mL portions of 3/1 CH₂Cl₂/MeOH and three 25 mL portions of 1/1 CH₂Cl₂/MeOH. The first two CH₂Cl₂ extracts were discarded and the remaining extracts were combined, dried (Na₂SO₄), filtered, and concentrated to give 102 mg of a viscous oil. Purification by HPLC (C₁₈, 23/77/0.1

-71-

CH₃CN/H₂O/CF₃CO₂H, 234 nm detection) provided 43 mg (14%) of compound 46 as a viscous oil: ¹H NMR (CDCl₃) δ 2.48 (t, 6H); 3.40 (s, 6H), 3.44-3.54 (m, 14H), 3.56-3.62 (m, 12H), 3.63 (s, 12H), 3.67 (t, 6H), 3.91 (s, 6H), 6.90 (t, 3H), 7.10 (t, 3H); MS (FAB) m/e (relative intensity) MH⁺ [1103(17), 1105(42), 1107(41), 1109(18)], MNa⁺ [1125(38), 1127(100), 1129(99), 1131(39)].

10 Compound 47 - S-(6-hydroxyhexyl)isothiuronium chloride:
11.1 g (146 mmol) of thiourea was added to a solution of 16.6 mL (20.0 g, 146 mmol) of 6-chlorohexanol in 49 mL of ethanol and the mixture was refluxed for 24 hours. The mixture was cooled to 0° and the product crystallized.
15 The crystals were collected by vacuum filtration and dried to give 28.4 g (92%) of compound 47 as a white solid: mp 122-124°; ¹H-NMR (DMSO) 1.40 (m, 4H), 1.65 (m, 2H), 3.21 (t, 2H), 3.41 (t, 2H), 9.27 and 9.33 (overlapping broad singlets, 4H); Anal. Calc'd for C₇H₁₇ClN₂S: C, 39.51; H, 8.06; N, 13.17; S, 15.07. Found: C, 39.69; H, 8.00; N, 13.01; S, 15.16.

Compound 48 - 6-Mercaptohexan-1-ol: 9.25 g of NaOH pellets was added to a solution of 17.8 mg (83.6 mmol) of compound 47 in 120 mL of H₂O and 120 mL of EtOH. The mixture was refluxed for 4 hours. The mixture was carefully concentrated to approximately 75 mL and the concentrate was purified by vacuum distillation to provide 7.4 g (66%) of compound 48: bp 95-105° @ 5 mm Hg; ¹H NMR (CDCl₃) 1.41 (m, 9H), 2.59 (dt, 2H), 3.69 (t with underlying brd s, 3H); ¹³C NMR (CDCl₃) δ 24.5, 25.2, 28.0, 32.5, 33.9, 62.7; Anal. calc'd for C₆H₁₄OS: C, 53.68, H, 10.51; S, 23.89. Found: C, 53.35; H, 10.72; S, 23.60.

-72-

Compound 49 - Bis-(6-hydroxyhexyl)disulfide: A solution of 4.02 g (15.8 mmol) of I_2 in 90 mL of MeOH was added dropwise over a period of 10 minutes to a solution of 4.26 g (31.7 mmol) of compound 48 in 10 mL of MeOH and 13.7 mL (9.97 g, 98.5 mmol) of Et_3N under N_2 atmosphere and cooled in an ice bath. The cooling bath was removed and the mixture was stirred at ambient temperature for 4 hours. The mixture was concentrated on the rotary evaporator and purified by silica gel chromatography (1:1 hexane/EtOAc) to provide 3.12 g (73%) of compound 49 as a pale yellow solid: TLC R_f .18 (1:1 hexane/EtOAc); mp 38-48°; 1H NMR ($CDCl_3$) 1.15-2.20 (m, 16H), 2.73 (t, 4H), 3.70 (t, 4H); Anal. calc'd for $C_{12}H_{26}S_2O_2$: C, 54.09; H, 9.84; S, 24.06. Found: C, 54.85, H, 9.86; S, 24.11.

Compound 50 - Mono-O-(4',4''-dimethoxytriphenylmethyl)-bis-(6-hydroxyhexyl)disulfide: 3.97 g (11.7 mmol) of 4,4'-dimethoxytriphenylmethyl chloride was added to a solution of 3.12 g (11.7 mmol) of compound 49 and 45 mL of pyridine. The mixture was stirred at ambient temperature for 16 hours. Most of the pyridine was removed on the rotary evaporator and the residue was partitioned between 100 mL of saturated $NaHCO_3$ solution and 100 mL of EtOAc. The EtOAc layer was washed with 50 mL of saturated NaCl solution, dried (Na_2SO_4), filtered and concentrated to an oil. Purification by silica gel chromatography (9:1 CH_2Cl_2 /EtOAc) yielded 2.84 g (43%) of compound 50 as a viscous oil: TLC R_f .35 (9:1 CH_2Cl_2 /EtOAc); 1H NMR ($CDCl_3$) 1.41 (m, 8H), 1.65 (m, 8H), 2.70 (two overlapping triplets, 4H), 3.08 (t, 2H), 3.65 (t, 2H), 3.81 (s, 6H), 6.85 (d, 4H), 7.32 (m, 7H), 7.47 (d, 2H); HRMS (FAB, M^+), calc'd for $C_{33}H_{44}O_4S_2$: 568.2681. Found: 568.2665.

-73-

Compound 51 - O-[14-(4',4''-Dimethoxytriphenylmethoxy)-7,8-dithiotetradecyl]-O-(2-cyanoethyl)-N,N-diisopropylphosphoramidite: 458 mg (1.52 mmol) of O-cyanoethyl-N,N,N',N'-tetra-isopropylphosphorodiamidite in 0.5 mL of CH₂Cl₂ was added to a solution of 771 mg (1.36 mmol) of compound 50 and 116 mg (0.68 mmol) of diisopropylammonium tetrazolidate in 6.8 mL of CH₂Cl₂ under N₂ atmosphere. The mixture was stirred for 4 hours and partitioned between 25 mL of NaHCO₃ and 3 x 25 mL of CH₂Cl₂. The combined CH₂Cl₂ layers were washed with saturated NaCl solution, dried (Na₂CO₃), filtered and concentrated to an oil. Purification by filtration through a 2" plug of basic alumina in a 25 mm column, eluting with 9:1 CH₂Cl₂/Et₃N provided 831 mg (80%) of compound 51 as a viscous oil: ¹H NMR (CDCl₃) δ 1.25 (m, 12H), 1.45 (m, 8H), 1.70 (m, 8H), 2.72 (m, 6H), 3.09 (t, 2H), 3.65 (m, 4H), 3.87 (s, 6H), 3.91 (m, 2H), 6.89 (d, 4H), 7.35 (m, 7H), 7.49 (d, 2H); ³¹P NMR (CDCl₃ with 15% H₃PO₄ internal standard) 147.69; HRMS (FAB, MH⁺) calc'd for C₄₂H₆₂N₂O₅PS₂ 769.3839, found 769.3853.

Compound 52 - Trityl-HAD alcohol: 60 g (0.21 mol) of trityl chloride was added to a solution of 57 g (0.21 mole) of compound 49 and 60 mL of pyridine. This mixture was stirred at 100°C for 19 hours. The reaction mixture was cooled to room temperature and filtered. The filtrate was diluted with 300 mL of methylene chloride and extracted by 200 mL of saturated sodium bicarbonate. The organic layer was dried over Na₂SO₄, filtered and concentrated to an oil. Purification by silica gel chromatography (gradient 9:1 hexanes: ethyl acetate 3:1 hexanes:ethyl acetate) yielded 55 g of compound 52 (50%): ¹H NMR (CDCl₃) δ 1.38 (m, 8H), 1.63 (m, 8H), 2.66 (m, 4H),

-74-

3.04 (t, 2H), 3.62 (t, 2H), 7.25 (m, 9H), 7.42 (m, 6H).
HRMS (FAB, M+) calc'd for $C_{31}H_{40}O_2S$ 508.2470, found
508.2482.

5 Compound 53 - Trityl HAD Phosphoramidite: To a solution
of 10 g (19.7 mmol) of compound 52 and 6.3 mL (36.2 mmol)
of diisopropylethylamine in 90 mL of methylene chloride
at 0°C under argon was slowly added 4.5 mL (20.2 mmol) of
10 2-cyanoethyl-N,N-diisopropylchlorophosphoramidite. After
stirring for 90 minutes, the reaction mixture was
extracted twice with 100 mL of saturated sodium
bicarbonate. The methylene chloride solution was dried
over Na_2SO_4 , filtered and concentrated to an oil.
15 Purification by basic alumina chromatography (75:24:1,
hexanes:ethyl acetate:triethylamine) provided 11.3 g
(81%) of compound 53 as an oil: 1H NMR ($CDCl_3$) δ 1.18 (m,
12H), 1.37 (m, 8H), 1.62 (m, 8H), 2.6 (m, 6H), 3.04 (t,
2H), 3.60 (m, 4H), 3.82 (m, 2H), 7.26 (m, 6H), 7.44 (m,
20 9H). HRMS (FAB, MH+) calc'd for $C_{40}H_{58}N_2O_3PS_2$ 709.3626,
found 709.3621.

Compound 54 - O-(tert-butyldimethylsilyl)-5-hexenol:
15.66 g (230 mmol) of imidazole and 20.0 g (130 mmol) of
25 tert-butyldimethylsilyl chloride were added to a solution
of 12.47 mL (10.4 g, 104 mmol) of 5-hexene-1-ol in 104 mL
of DMF. The mixture was stirred at ambient temperature
for 4 hours and partitioned between 200 mL of EtOAc and
100 mL of saturated $NaHCO_3$ solution. The EtOAc layer was
30 washed with 100 mL of saturated $NaHCO_3$ solution, 100 mL
of saturated NaCl solution, dried ($MgSO_4$), filtered, and
concentrated to a volume of approximately 100 mL.
Distillation under vacuum provided 70.07 g (90%) of
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-75-

compound 54: bp 130-143° @ 100 mm Hg; ¹H NMR (CDCl₃) 0.11 (s, 6H), 0.95 (s, 9H), 1.48 (m, 2H), 1.57 (m, 2H), 2.11 (dt, 2H), 3.66 (t, 2H), 5.03 (m, 2H), 5.86 (m, 1H); ¹³C NMR (CDCl₃) -5.25, 18.40, 25.21, 26.01, 32.35, 33.60, 63.09, 114.40, 138.92; Anal. calc'd for C₁₂H₂₆OSi: C, 67.22; H, 12.22. Found: C, 66.96; H, 12.16.

Compound 55 - 1-O-(tert-butyldimethylsilyl)-1,5,6-hexanetriol: To a solution of 9.86 g (46.0 mmol) of compound 54 in 92 mL of acetone was added a solution of 6.46 g (55.2 mmol) of N-methylmorpholine oxide in 23 mL of H₂O. To the mixture was added 443 μl of a 2.5% solution of OsO₄ in tert-butyl alcohol (360 mg of solution, 9.0 mg of OsO₄, 35 μmol) and 50 μL of 30% H₂O₂. The mixture was stirred for 16 h and a solution of 474 mg of sodium dithionite in 14 mL of H₂O was added. After another 0.5 h the mixture was filtered through celite. The filtrate was dried with MgSO₄ and filtered through 1" of silica gel in a 150 mL Buchner funnel using 250 mL portions of EtOAc to elute. Fractions containing product were concentrated to provide 11.0 g (96%) of 55 as a viscous oil: TLC R_f 0.2 (1:1 hexane/EtOAc); ¹H NMR (CDCl₃) 0.05 (s, 6H), 0.89 (s, 9H), 1.25 (m, 4H), 1.55 (m, 2H), 3.41 (dd, 2H), 3.62 (t, 2H), 3.71 (m, 1H); ¹³C NMR (CDCl₃) -5.23, 18.42, 21.91, 26.02, 32.68, 32.81, 63.16, 66.74, 72.24; HRMS (FAB, MH⁺), calc'd for C₁₂H₂₈O₃Si: 249.1886. Found : 249.1889.

Compound 56 - 5,6-(bis-O-benzoyl)-1-O-(tert-butyldimethylsilyl)-1,5,6-hexanetriol: 6.18 mL (7.48 g, 53.2 mmol) of benzoyl chloride was added to a solution of 5.29 g (21.3 mmol) of 55 in 106 mL of pyridine. The mixture was stirred for 18 hours and concentrated on the

-76-

rotary evaporator. The mixture was partitioned between 100 mL of cold 1 N HCl and 100 mL of EtOAc. The pH of the aqueous layer was checked to make sure it was acidic. The EtOAc layer was washed successively with 100 mL of H₂O and 100 mL of saturated NaCl, dried (MgSO₄), filtered, and concentrated to provide 10.33 g (99%) of compound 56 as a viscous yellow oil: TLC R_f 0.45 (1:4 EtOAc/hexanes); ¹H NMR (CDCl₃) δ 0.05 (s, 6H), 0.88 (s, 9H), 1.59 (m, 4H), 1.85 (m, 2H), 3.14 (t, 2H), 4.49 (dd, 1H), 4.59 (dd, 1H), 5.54 (m, 1H), 7.45 (m, 4H), 7.58 (m, 2H), 8.05 (m, 4H).

Compound 57 - 5,6-(bis-O-benzoyl)-1,5,6-hexanetriol:
10.7 mL (10.7 mmol) of 1 N tetrabutylammonium fluoride in THF was added to a solution of 2.62 g (5.36 mmol) of compound 56 in 10.9 mL of THF. The mixture was stirred for 16 hours. The mixture was partitioned between 25 mL of saturated NaHCO₃ solution and 3 x 25 mL of EtOAc. The combined EtOAc extracts were washed with saturated NaCl solution, dried (MgSO₄), filtered and concentrated to a viscous oil which was purified by silica gel chromatography (1:1 hexane/EtOAc) to provide 823 mg (41%) of compound 57 as a viscous oil; R_f 0.14 (1:1 hexane/EtOAc); ¹H NMR (CDCl₃) δ 1.58 (m, 2H), 1.68 (m, 2H), 1.88 (m, 2H), 3.68 (t, 2H), 4.52 (dd, 1H), 4.62 (dd, 1H), 5.56 (m, 1H), 7.46 (m, 4H), 7.58 (m, 2H), 8.05 (m, 4H); ¹³C NMR (CDCl₃) δ 22.08, 31.20, 31.30, 32.88, 62.92, 66.17, 72.63, 128.93, 130.19, 130.57, 133.62, 166.72, 166.86; HRMS (FAB MH⁺), calc'd for C₂₀H₂₃O₅; 343.1545.
Found: 343.1553.

Compound 58 - O-[5,6-(bis-O-benzoyloxy)-hexyl]-O-(2-cyanoethyl)-N,N-diisopropylphosphoramidite: A solution of 989 mg (3.28 mmol) of O-cyanoethyl-N,N,N', N'-

-77-

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tetraisopropylphosphorodiamidite in 2.0 mL of CH_2Cl_2 was added to a solution of 1.02 g (2.98 mmol) of compound 57 and 255 mg (1.49 mmol) of diisopropylammonium tetrazolide (prepared by mixing acetonitrile solutions of diisopropylamine and tetrazole in a one-to-one mole ratio and concentrating to a white solid) in 14.9 mL of CH_2Cl_2 . The mixture was stirred for 4 hours and then partitioned between 25 mL of CH_2Cl_2 and 25 mL of chilled saturated NaHCO_3 solution. The CH_2Cl_2 layer was washed with saturated NaCl solution, dried (Na_2SO_4), filtered, and concentrated. Purification by filtration through a 2" plug of basic alumina in a 25 mm column, eluting with 9:1 EtOAc/ Et_3N , provided 1.5 g (93%) of compound 58 as a viscous oil: ^1H NMR (CDCl_3) δ 1.19 (m, 12H), 1.62 (m, 2H), 1.73 (m, 2H), 1.90 (m, 2H), 2.62 (dd, 2H), 3.53-3.92 (m, 6H), 4.53 (dd, 1H), 4.62 (dd, 1H), 5.58 (m, 1H), 7.48 (m, 4H), 7.60 (m, 2H), 8.09 (m, 4H); ^{31}P NMR (CDCl_3 with 15% H_3PO_4 internal standard) δ 148.2; HRMS (FAB, MH^+), calc'd for $\text{C}_{29}\text{H}_{40}\text{O}_6\text{N}_2\text{P}$ 543.2624. Found, 543.2619.

Compound 59 - [4(iodoacetamido)benzoic acid]: This compound was prepared as described by Weltman, J.K., 1983 Biotechniques 1:148-152. Briefly, 708 mg (2.0 mmol) of iodoacetic anhydride was added to a solution of 137 mg (1.0 mmol) of para-aminobenzoic acid in 10 mL of dioxane. The mixture was stirred in the dark for 18 hours and partitioned between 25 mL of H_2O and 25 mL of EtOAc. The EtOAc layer was washed with saturated NaCl solution, dried (MgSO_4), filtered and concentrated to yield 797 mg of a peach colored solid. Recrystallization from hexanes/EtOAc yielded 221 mg (72%) of 4-(iodoacetamido)benzoic acid as a white solid: mp 220-

-78-

230°; ¹H NMR (CDCl₃) d 3.86 (s, 2H), 7.68 (d, 2H), 7.91 (d, 2H), 10.60 (s, 1H).

5 Compound 60 - [4-(iodoacetamido)benzoyl derivative of
α,ω-bis-(N-2-aminoethylcarbamoyl)polyethyleneglycol:
188 mg (0.909 mmol) of dicyclohexylcarbodiimide was added
to a solution of 185 mg (0.606 mmol) of 4-
(iodoacetamido)benzoic acid and 406 mg (0.121 mmol) of
10 α,ω-bis-(N-2-aminoethylcarbamoyl)polyethyleneglycol
(Sigma Chemical Co., St. Louis, MO., dried by azeotropic
distillation with toluene) in 2 mL of THF. The mixture
was stirred for 2 hours and then six drops of acetic acid
were added. 10 mL of CH₂Cl₂ was added and the mixture was
kept in a freezer for 30 minutes. The mixture was
15 filtered to remove solids and the filtrate was
concentrated to a viscous residue. Purification by
silica gel chromatography (gradient 99/1 to 96/4
CH₂Cl₂/MeOH) provided a solid which was triturated with
MeOH to give 292 mg of a cream colored solid: ¹H (CDCl₃)
20 3.48 (m, 8H), 3.63 (bd s, (CH₂CH₂O)_n, integral too large
to integrate), 3.98 (s, 4H), 4.18 (bd m, 4H), 5.91 (bd m,
2H), 7.48 (bd m, 2H), 7.76 (d, 4H), 7.88 (d, 4H), 9.38
(bd m, 2H): iodoacetyl determination (European Journal
of Biochemistry 1984, 140, 63-71): Calculated, 0.46
25 mmol/g; Found, 0.37 mmol/g.

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-79-

Example 3

Preparation of Activated Valency Platform Molecules
and Conjugates

5 There are many ways to form conjugates of biological
or chemical molecules and valency platform molecules. A
particularly specific method uses a thiol attached to the
biological or chemical molecule to react nucleophilically
10 with a reactive "thiophillic" group on the valency
platform molecule to form a thioether bond, but other
combinations of reactive groups on the platform molecule
and on the biological or chemical molecule can also be
employed for attaching biological or chemical molecules
15 covalently to a valency platform molecule. Table 1
contains a number of combinations of mutually reactive
groups. The preference of any given method is dictated
by the nature of the biological or chemical molecule
(solubility, presence of other reactive groups, etc.).

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Table 1

Nucleophile	Mutually Reactive Group
amine, hydrazide hydrazine	active ester, anhydride, acid halide, sulfonyl halide, imidate ester, isocyanate, isothiocyanate, chloroformate carbodiimide adduct, aldehyde, ketone
sulfhydryl	haloacetyl, alkyl halide, alkyl sulfonate, maleimide, α,β - unsaturated carbonyl, alkyl mercurial, sulfhydryl, α,β - unsaturated sulfone

The following examples illustrate how various valency platform molecules can be synthesized and conjugated with biological or chemical molecules. These examples show how peptides and oligonucleotides can be conjugated to valency platform molecules using some of the mutually reactive groups in Table 1. In addition to peptides and oligonucleotides, other biologically active molecules (proteins, drugs, etc.) can also be conjugated to valency platform molecules.

-81-

Combination 1: Thiol on Platform - Thiophile on Ligand

Reaction Scheme 14

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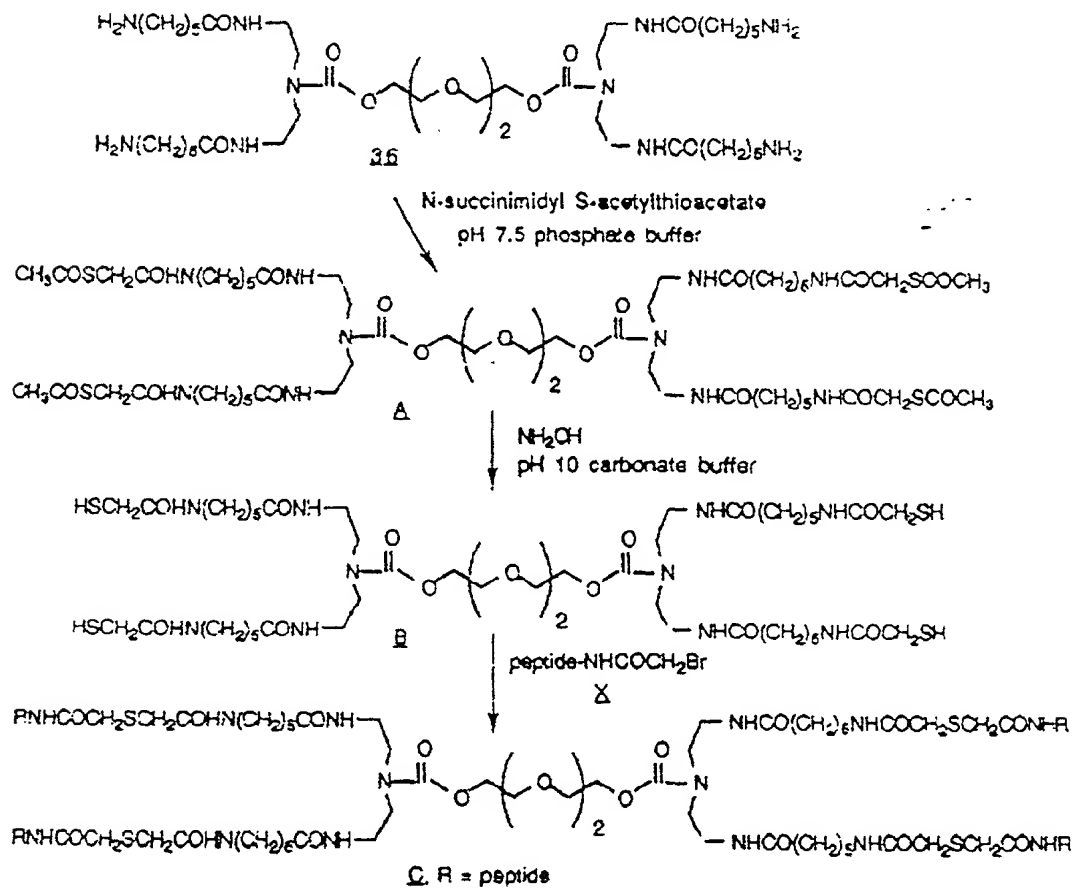
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-82-

Compound A: Compound 36 (861 mg, 1.0 mmol) and 252 mg (3.0 mmol) of NaHCO₃ are dissolved in 20 mL of 1/1 dioxane/H₂O. The mixture is cooled to 0°, and a solution of 1.16 g (5.0 mmol) of N-succinimidyl-S-acetylthioacetate (Prochem Inc.) in 40 mL of dioxane is added to the stirred mixture. After 1 hour the mixture is extracted with CH₂Cl₂. The combined extracts are dried (MgSO₄), filtered, and concentrated. The crude product is purified by silica gel chromatography to provide A.

Compound B - Platform with Four Thiol Groups. A solution of 732 mg (0.55 mmol) of A in 7.3 mL of DMSO is added to 55 mL of helium sparged pH 10, 100 mM sodium carbonate, 10 mM NH₂OH buffer. The mixture is kept under N₂ and stirred for 1 hour to obtain an approximately 10 mM solution of tetra-thiol platform B.

Compound X - Bromoacetylated Peptide: A peptide is synthesized with standard solid phase methods on a Wang (p-alkoxybenzyl) resin using Fmoc chemistry. Fmoc protected amino acids are added sequentially to the amino terminus. The final step involves coupling N-bromoacetylaminocaproic acid. The protecting groups are removed, and the peptide is removed from the resin with trifluoroacetic acid to give X which is purified by preparative reverse phase HPLC.

Peptide - Platform Conjugate, C. To the approximately 10 mmol solution of tetrathiol platform, B, in pH 10 buffer, is added an excess of a solution of bromoacetylated peptide, X, in DMSO. The peptide conjugate, C, is purified by preparative reverse phase HPLC.

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Compound Y - Peptide with Activated Carboxylate. A peptide is synthesized with standard solid phase methods on a Wang (p-alkoxybenzyl) resin, using TFA stable protecting groups (benzyl ester on carboxyl groups and CBZ on amino groups). Amino acid residues are added sequentially to the amino terminus. The peptide is removed from the resin with TFA to provide a peptide with one free carboxyl group at the carboxy terminus and all the other carboxyls and amines blocked. The protected peptide, Y, is purified by reverse phase HPLC.

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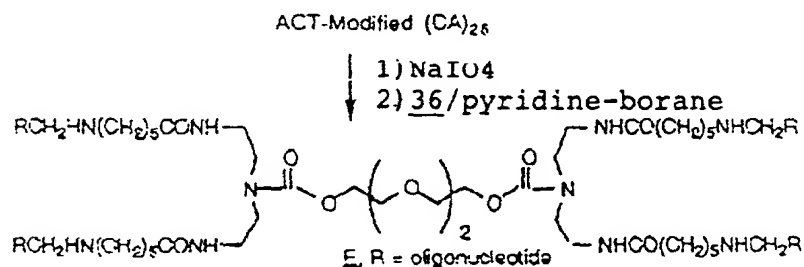
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-84-

apparatus with 100 mg of 10% Pd/C per gram of conjugate.
 The mixture is shaken under 60 psi H₂, and the
 deprotected conjugate, D, is purified by preparative
 reverse phase HPLC.

Combination 3: Amine on Platform - Aldehyde on
 Oligonucleotide

Reaction Scheme 16



Oligonucleotide - Platform Conjugate, E. A 500 uL
 aliquot (100 umol) of a 200 mM solution of NaIO₄ is added
 to a solution of 1.0 g (400 mg of full length, 25 umol)
 of ACT-modified (CA)₂₈ in 19.5 mL of H₂O at 0° in the
 dark. The mixture is kept at 0° for 40 minutes, and 50
 mL of EtOH is added. The mixture is kept at -20° for 30
 minutes and centrifuged for 5 minutes at 2000 RPM. The
 supernatant is discarded, and the pellet is dried under
 vacuum. The pellet is dissolved in 3.3 mL of H₂O, and to
 the resulting solution is added a solution of 4.3 mg
 (0.005 mmol) of 36 in 2.0 mL of pH 8.0 100 mM sodium

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-86-

Compound F - Platform with Four Carboxylic Acid Groups.

Succinic anhydride (1.0 g, 10 mmol) is added to a solution of 861 mg (1.0 mmol) of 36 and 252 mg (3.0 mmol) of NaHCO₃ in 20 mL of 1/1 dioxane/H₂O, and the mixture is stirred for 16 h at room temperature. The mixture is acidified with 1 N HCl and concentrated. The concentrate is purified by silica gel chromatography to provide F.

Compound G - Platform with Four N-Hydroxysuccinimidyl

Esters. A solution of 126 mg (0.1 mmol) of F and 46 mg (0.4 mmol) of N-hydroxysuccinimide in 5 mL of anhydrous THF is prepared. The mixture is cooled to 0° and 103 mg (0.5 mmol) of dicyclohexylcarbodiimide is added. The mixture is stirred allowing to come to room temperature over several hours. The solids are removed by filtration, and the filtrate is concentrated to provide G which can be purified by silica gel chromatography.

Compound Z - Peptide with Amino Group. A peptide is synthesized with standard solid phase methods on a Wang (p-alkoxybenzyl) resin. Lysine ε-amines are protected as CBZ groups. Amino acid residues are added sequentially to the amino terminus using Fmoc chemistry. The last residue added is N-Fmoc-aminocaproic acid. After cleaving from the resin with trifluoroacetic acid, the Fmoc group is removed with piperidine to provide a peptide with a free amine linker. The peptide, Z, is purified by reverse phase HPLC.

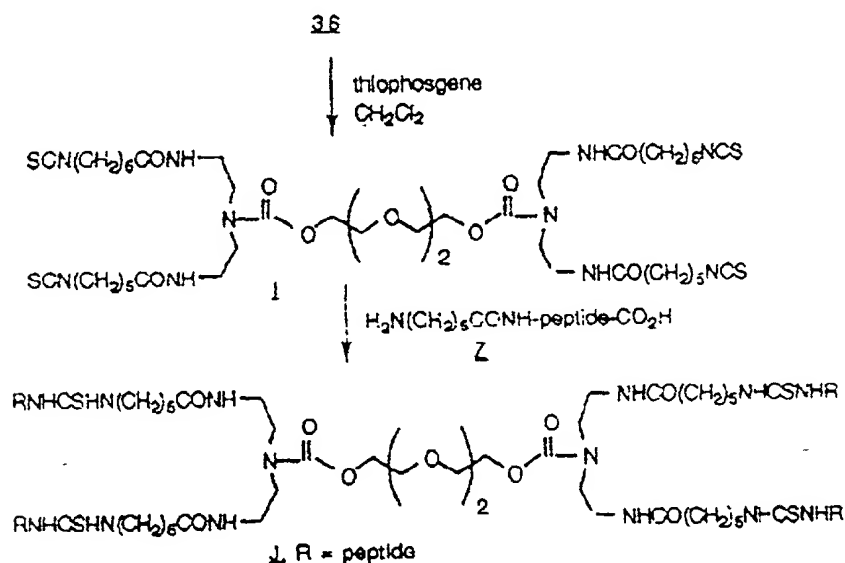
Peptide - Platform Conjugate, H. A solution of 0.05 mmol of Z and 0.1 mmol of Et₃N in 1 mL of DMF is prepared. To the solution is added a solution of 16.5 mg (0.01 mmol) of G in 1 mL of DMF. The mixture is stirred until the

-87-

reaction is complete. To remove protecting groups, the conjugate is dissolved in MeOH, and the solution is placed in a Parr hydrogenation apparatus with 100 mg of 10% Pd/C per gram of conjugate. The mixture is shaken under 60 psi H₂, and the deprotected conjugate, H, is purified by preparative reverse phase HPLC.

Combination 5: Isothiocyanate on Platform - Amine on Ligand

Reaction Scheme 18



Compound 1 - Platform with Four Isothiocyanates.

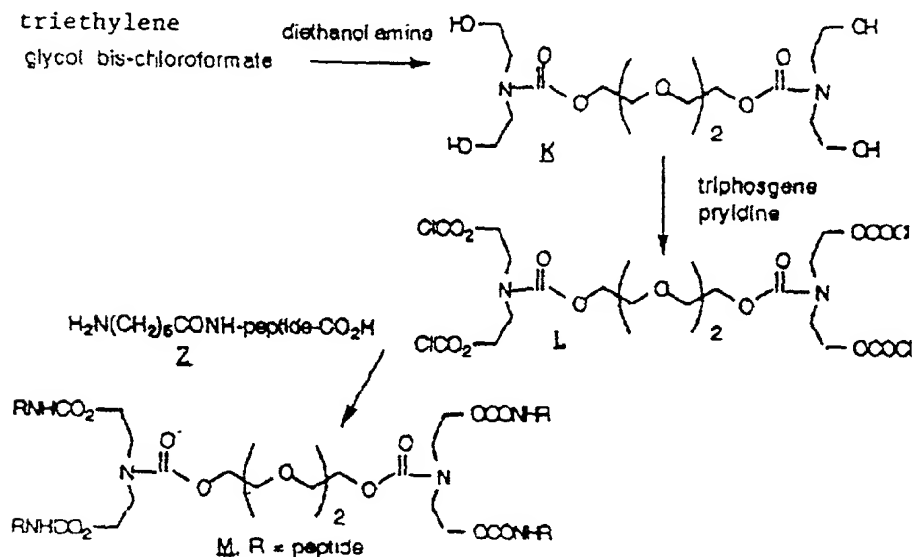
Thiophosgene (381 uL, 575 mg, 5.0 mmol) is added to a solution of 861 mg (1.0 mmol) of 36 in 10 mL of THF, and the mixture is stirred at room temperature until complete by TLC. The mixture is partitioned between methylene chloride and a solution of 5% NaHCO₃. The extracts are dried (MgSO₄), filtered, and concentrated. The product, I, is purified by silica gel chromatography.

-88-

Peptide - Platform Conjugate, J. A solution of 0.05 mmol of Z and 0.1 mmol of Et₃N in 1 mL of DMF is prepared. To the solution is added a solution of 10.3 mg (0.01 mmol) of I in 1 mL of DMF. The mixture is stirred until the reaction is complete. To remove protecting groups, the conjugate is dissolved in MeOH, and the solution is placed in a Parr hydrogenation apparatus with 100 mg of 10% Pd/C per gram of conjugate. The mixture is shaken under 60 psi H₂, and the deprotected conjugate, J, is purified by preparative reverse phase HPLC.

Combination 6: Chloroformate on Platform - Amine on Ligand

Reaction Scheme 19



-89-

Compound K - Platform with Four Hydroxyl Groups. A solution of 205 uL (275 mg, 1 mmol) of triethylene glycol bis-chloroformate in 5 mL of CH_2Cl_2 is added to a solution of 497 uL (525 mg, 5 mmol) of diethanolamine and 696 uL (506 mg, 5 mmol) of Et_3N in 5 mL of CH_2Cl_2 at 0° . The mixture is allowed to warm to room temperature and stirred until complete as evidenced by TLC. The mixture is concentrated and the product, K, is isolated by silica gel chromatography.

Compound L - Platform with Chloroformate Groups. Pyridine (100 uL) followed by 1.19 g (4 mmol) of triphosgene are added to a solution of 412 mg (1 mmol) of K in 20 mL of CH_2Cl_2 . The mixture was stirred at room temperature for 20 hours, and the solvent was evaporated under vacuum to give compound L.

Peptide - Platform Conjugate, M. A solution of 1 mmol of Z in 10 mL of pyridine is added to a solution of 132 mg (0.2 mmol) of L in 5 mL of 1/1 THF/pyridine. The mixture is stirred until the reaction is complete. Solvents are removed in vacuo. To remove protecting groups, the conjugate is dissolved in MeOH, and the solution is placed in a Parr hydrogenation apparatus with 100 mg of 10% Pd/C per gram of conjugate. The mixture is shaken under 60 psi H_2 , and the deprotected conjugate, M, is purified by preparative reverse phase HPLC.

-90-

Example 4
Synthesis of Conjugates Comprising Two
Different Biological Molecules

5 It can be useful to conjugate more than one kind of
biologically active group to a platform molecule. This
example describes the preparation of a platform
containing two maleimide groups, which react with a
10 thiol-containing peptide, and two activated ester groups,
which react with a drug containing a free amine. The
resulting conjugate contains two peptides and two drug
molecules as shown in Scheme 20.

15 Preparation of heteroactivated valency platform molecule
Benzyl 6-aminocaproate tosylate salt, K: A mixture of 32
mmol of 6-aminocaproic acid, 51 mmol of p-toluenesulfonic
acid, and 40 mmol of benzyl alcohol in 60 mL of toluene
is refluxed using a Dean-Stark trap to remove water.
20 When the reaction is complete, the mixture is cooled, and
the product precipitates. The solid is collected by
filtration and recrystallized from EtOH/Et₂O to provide
compound K.

25 Compound L: Dicyclohexylcarbodiimide (2 equivalents) is
added to a solution of 1 equivalent of compound 5 and 2
equivalents of N-hydroxysuccinimide in THF. The mixture
is stirred for 4 hours and 2.2 equivalents of compound K
is added. The mixture is stirred until the reaction is
30 complete as evidenced by TLC. The mixture is filtered
and concentrated. The product is purified by silica gel
chromatography.

35

-91-

Compound M: Compound L is treated with trifluoroacetic acid in CH_2Cl_2 . When the reaction is complete, the mixture is concentrated under vacuum to provide compound M as the trifluoroacetate salt.

Compound N: Compound 6 (Scheme 2) is treated with trifluoroacetic acid in CH_2Cl_2 . When the reaction is complete, the mixture is concentrated under vacuum to provide compound N as the trifluoroacetate salt.

Compound O: 3.2 mmol of triethyleneglycol bis-chloroformate is added to a solution of 4 mmol of compound M and 4 mmol of compound N in 162 mL of pyridine in a 20° water bath. The mixture is stirred until complete by TLC and concentrated under vacuum. The concentrate is dissolved in CH_2Cl_2 and washed successively with 1 N HCl solution, 5% NaHCO_3 solution, and saturated NaCl solution. The CH_2Cl_2 layer is dried (MgSO_4), filtered and concentrated. The concentrate is dissolved in 10 mL of EtOH and 10 mL of 1 M NaOH is added. The mixture is stirred for several hours, until no further reaction appears to take place by TLC. The mixture is acidified to pH 1 with 1 N HCl and extracted with CH_2Cl_2 . The CH_2Cl_2 layer is dried (MgSO_4), filtered, and concentrated. The product, Q, is isolated by silica gel chromatography.

Compound P: Compound Q is dissolved in EtOH and hydrogenated in a Parr shaker with 100 mg of 10% palladium on carbon per gram of Q. The reaction is monitored for completeness by TLC. When the reaction is

-92-

complete, the catalyst is removed by filtration, and the mixture is concentrated to yield compound P.

5 Compound Q: 3 mmol of N-methoxycarbonylmaleimide is added to a solution of 1 mmol of compound P in 20 mL of dioxane and 5 mL of saturated NaHCO₃ at 0°. The mixture is stirred for an hour, acidified with 1 N HCl, and extracted with CH₂Cl₂. The CH₂Cl₂ layer is dried (MgSO₄),
10 filtered, and concentrated, and the product is purified by silica gel chromatography to yield Q.

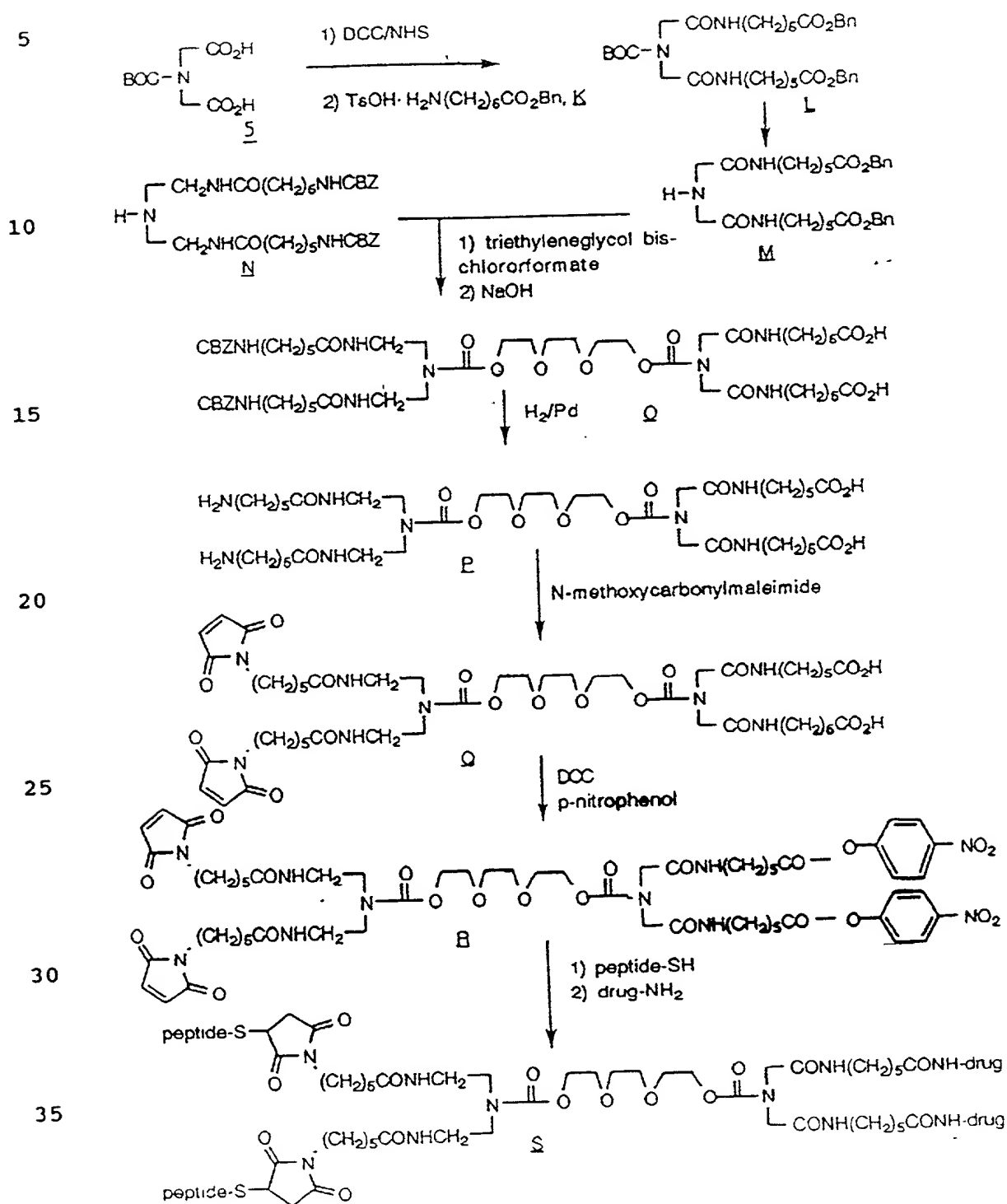
Compound R: 2 mmol of DCC is added to a solution of 1 mmol of Q and 2 mmol of p-nitrophenol in CH₂Cl₂, and the
15 mixture is stirred for 16 h. The solids are removed by filtration, and the filtrate is concentrated and purified by silica gel chromatography to yield R.

Conjugate with two peptides and two drug molecules.
20 compound S: An excess of two equivalent of thiol-containing peptide is added to a solution of 1 equivalent of heteroactivated platform, R, in pH 7.5 phosphate buffer. The mixture is stirred for 1 hour, and excess of two equivalents of amine-containing drug is added. The
25 conjugate, S, is isolated by reverse-phase HPLC or ion-exchange chromatography or a combination of both.

30

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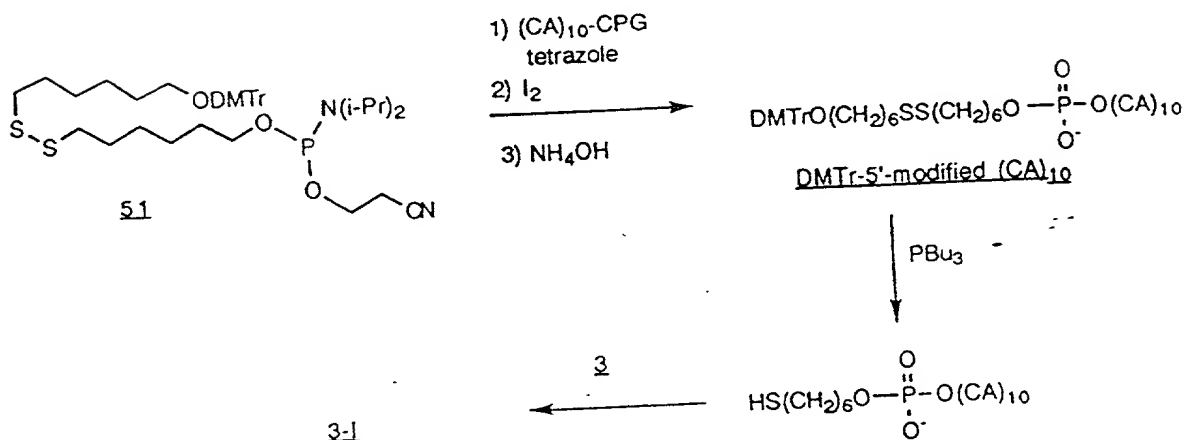
Reaction Scheme 20



-94-

Example 5
Synthesis and Testing of Conjugate 3-II
Reaction Scheme 21

5



Preparation of DMTr-5'-Modified (CA)₁₀

20 The polynucleotide d-[DMTr-(bzCp(CE)bZA)₁₀] was prepared on a Milligen 8800 Prep Scale DNA synthesizer (See Figure 6A) following the manufacturer's protocols for DNA phosphoramidite synthesis. The synthesis was carried out on 10 g of DMTr-d-bZA-CPG support with a nucleoside loading of 30.0 μmol/g. The final DMTr

25 blocking group was removed using the machine protocol. Milligen activator solution, Cat. No. MBS 5040 (45 mL) and 0.385 g of compound 51 (see Reaction Scheme 11) were added to the reaction and the suspension was mixed for 8

30 minutes by argon ebullition. The mixture was oxidized by the usual machine protocol and the support-bound polynucleotide was collected by filtration, air dried and treated with 100 mL of concentrated ammonia for 16 hours

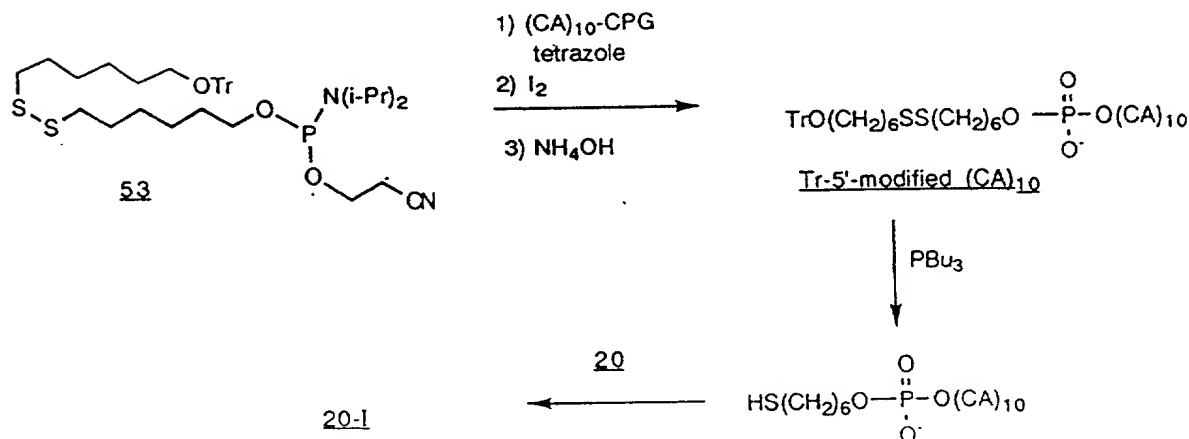
35 at 55°C. When cool, the mixture was filtered through a

-95-

Gelman 10 μ polypropylene filter. The filter was washed with 200 mL of 2 mM NaCl adjusted to pH 12 with NaOH. The filtrate was then applied to a Amicon chromatography column (0.45 x 9.4 cm, 150 mL) which had been packed with Q-Sepharose (Pharmacia) equilibrated first with 3M NaCl and then with 2 mM NaCl, pH 12. The column was eluted with 500 mL of a linear gradient (2 mM NaCl, pH 12 to 1.3 M NaCl, pH 12), then washed with 1.3 M NaCl, pH 12 until all U.V. absorbing material came off. Fractions which absorbed at 260 nm were further analyzed by polyacrylamide electrophoresis and those containing pure product were pooled. The pool (120 mL) was treated with 240 mL of cold isopropanol and stored for 30 minutes at -20°C. The precipitate was collected by centrifugation in a Sorvall RC 3B centrifuge using a model H-6000A rotor for 15 minutes at 3000 rpm and 4° C to yield DMTr-5'-modified (CA)₁₀ (14946 A₂₆₀ units, 498 mg, 62.2 μ M, 20% based on 300 μ M, CPG nucleoside.)

Synthesis of a Tr-5'-Modified (CA)₁₀

Reaction Scheme 22



-96-

The synthesis of Tr-5'-modified (CA)₁₀ was carried out as described above for the synthesis of DMTr-5'-modified (CA)₁₀ (prepared as described in Reaction Scheme 11) by substituting compound 53 for compound 51.

Conjugation of DMTr-5' Modified Polynucleotides to Compound 3 (IA-DABA-PEG, Reaction Scheme 1) - Preparation of Conjugate 3-I

In the conjugation procedures that follow, all the buffers and solutions employed were thoroughly sparged with helium and all reaction vessels were purged with argon before use. A solution of 11,568 A₂₆₀ units (48.2 μ mol, assume molar extinction at 260 nm = 240,000) of the DMTr-5'-modified (CA)₁₀ in 7.7 mL water was treated with 1 mL of 0.1 M NaHCO₃ and 210 μ L (876 μ mol, 18 times molar excess) tributylphosphine for 0.5 hour at room temperature. The suspension was shaken from time to time. The suspension was treated with 0.8 mL of 3M NaCl and 16 mL of cold isopropanol. After 30 minutes at -20°C, the material was centrifuged at 3000 rpm for 20 minutes. The pellet was redissolved in 2 mL of water, 0.2 mL of 3M NaCl, treated with 4 mL isopropanol and recentrifuged. The pellet was briefly dried under vacuum and dissolved in 2.8 mL of water and 1 mL of 0.1 N NaHCO₃, which had been sparged with helium. 6.7 mg of compound 3 (IA-DABA-PEG) was added, and the mixture was kept for 16 hours at room temperature in the dark. The reaction mixture in a final volume of 6 mL was applied to a 5 x 91 (1800 Ml) Pharmacia column which was packed with Sephacryl 200 (Pharmacia). The column was eluted with 0.5 M NaCl, 0.1 M sodium borate, pH 8.3. A peristaltic pump was used and set to give a flow rate of approximately 2 mL per min., and fractions of 15 ml were

-97-

collected. The absorbance of the fractions at 260 nm was measured. The fractions were also analyzed by polyacrylamide gel electrophoresis and those containing pure conjugate were pooled.

Hybridization of Conjugate 3-I - Preparation of Conjugate 3-II

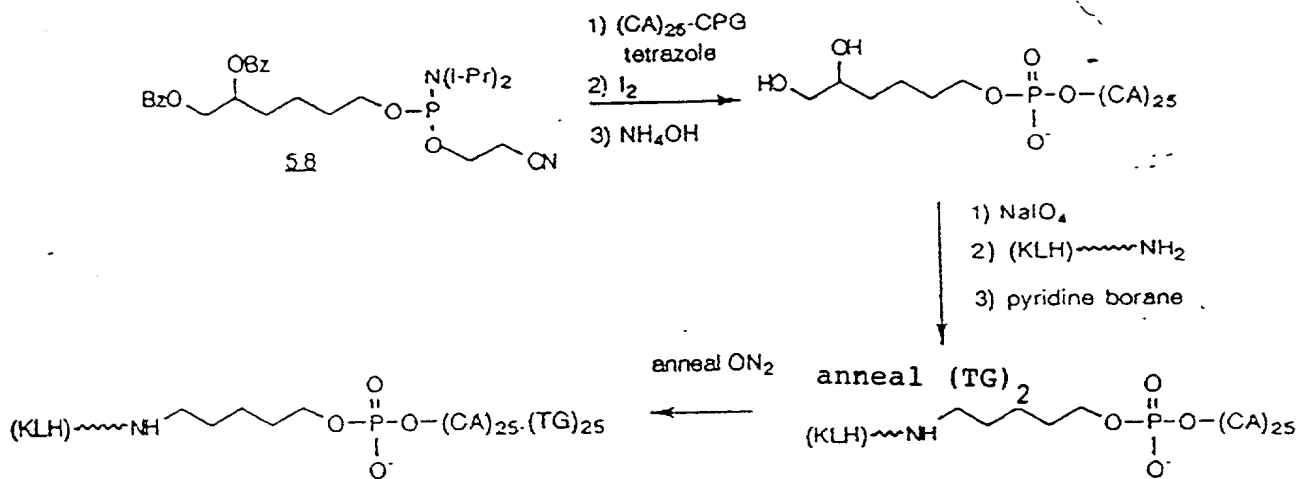
The pooled fractions from above contained 726 A_{260} units. The equivalent amount of $(TG)_{10}$ was added and the tube was heated at 90°C for ten minutes and then allowed to cool to room temperature over 1.5 hours. An equal amount of isopropanol was added and the mixture kept for 3 hours at -20°C. After centrifugation at 3000 rpm for 20 minutes, the pellet was dissolved in 0.15 M NaCl, 0.01 M sodium citrate, pH 6.8. 53 mg of the hybrid was obtained. An aliquot of the material was diluted in the above buffer and the melting temperature of the duplex was determined in a Carey 3E spectrophotometer. The material had a T_m of 73.4°C. and 24.3% hyperchromicity. A 10 A_{260} unit aliquot of the product was annealed with excess $(TG)_{10}$ as described above. This as well as unannealed conjugate and a $(TG)_{10}$ standard were analyzed by gel permeation HPLC on a Shodex Protein KW 8025 column on a Rainin HPLC instrument. The column was eluted isocratically with 0.05M NaH_2PO_4 , pH 6.5, 0.5M NaCl. The run time was 12 minutes. The product had a retention time of 6.9 minutes and $(TG)_{10}$ 9.2 minutes. Comparison of the area under the peaks showed that 98.09% of the product was double stranded DNA. The conjugate is represented by the structure designated "Conjugate 3-II" in Figure 6A.

-98-

Example 6

Preparation of PN-KLH Conjugate

The PN-KLH conjugate was prepared according to the
5 scheme below:



-99-

Synthesis of ACT-Modified (CA)₂₅

Compound 58 was coupled to (CA)₂₅ as the final step of automated synthesis. Forty-nine sequential steps were carried out using alternating dC and dA phosphoramidites beginning with 10 g of DMT-d-bzA-CPG support with a nucleoside loading of 30 $\mu\text{mol/g}$. The DMTr blocking group was removed from the resulting d-[DMTr-(bzCp(CE)bzA)₂₅], and 40 mL of activator solution (Milligen, Cat. No. MBS 5040) and 800 mg of compound 58 were added to the reaction mixture. The suspension was mixed for 8 minutes by argon ebullition and subjected to a conventional oxidation step. The support bound polynucleotide was removed from the reaction vessel, air dried, and treated with 100 mL of concentrated ammonia for 40 hours at 55°. When cool, the mixture was filtered through a Gelman 10 μm polypropylene filter and the filtrate was then purified by conventional ion exchange chromatography. Fractions which absorbed at 260 nm were further analyzed by polyacrylamide gel electrophoresis and those containing pure product were combined and precipitated with isopropanol to provide 510 mg (31.9 μmol , 10%) of the ACT-modified (CA)₂₅.

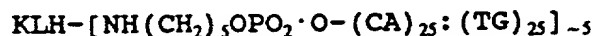
Synthesis of Single-stranded PN-KLH Conjugate

To a solution of 100 mg (2.5 μmol) of ACT-modified (CA)₂₅ in 1.33 mL of 50 mM sodium borate pH 8.0 was added 31.3 mg (0.208 μmol) of KLH and 2.0 mg (31.8 μmol) of NaCNBH₃. The mixture was kept at 37°C for 72 h, and the product was purified by chromatography on S-200.

-100-

Hybridization of Single-stranded PN-KLH Conjugate with (TG)₂₅

The equivalent amount of (TG)₂₅ was added to the single-stranded PN-KLH conjugate and the tube was heated at 90°C for ten minutes and then allowed to cool to room temperature over an hour and a half. Precipitation with isopropyl alcohol yielded 53 mg of 1%; T_m (0.15 M NaCl, 0.01 M sodium citrate, pH 6.8) 73.4°, 31.1% hyperchromicity; 98% double stranded as determined by HPLC comparison to standards consisting of sample annealed with excess (TG)₁₀, unannealed conjugate, and unannealed (TG)₁₀ (Shodex Protein KW 8025 column, 0.05 M NaH₂PO₄, pH 6.5, 0.5 M NaCl). This conjugate may be represented by the formula



(assuming a molecular weight of 10⁵ for KLH) and is designated "PN-KLH."

Testing of Conjugate 3-II as a Tolerogen

Conjugate 3-II was tested for its ability to tolerize mice that had been immunized with an immunogenic form of the polynucleotide.

Material and Methods

Mice: C57BL/6 female mice 6 weeks of age were purchased from Jackson Laboratories, Bar Harbor, ME. The mice were housed and cared for by NIH approved methods.

Immunization: The mice were primed, according to the method of Iverson (Assay for in vivo Adoptive Immune Response in Handbook of Experimental Immunology, Vol. 2 Cellular Immunology, Eds. D.M. Weir, L.A. Herzenberg, C.

-101-

Blackwell and A. Herzenberg, 4th Edition, Blackwell Scientific Publications, Oxford) by injecting the mice, i.p., with 100 μ g of PN-KLH precipitated on alum and with 2 x 10⁹ formalin fixed pertussis organisms as an adjuvant. The mice were boosted with 50 μ g of PN-KLH, in saline, i.p.

Coupling of PN to SRBC: Sheep Red Blood Cells (SRBC) in Alsevers were purchased from Colorado Serum Co., Denver, CO, and used within two weeks. The SRBC were coated with (CA)₂₅:(TG)₂₅ (a 50 mer of CA:GT) by the method of Kipp and Miller ("Preparation of Protein-Conjugated Red Blood Cells with ECDI (Modification)" in Selected Methods in Cellular Immunology, (1980), Eds. B.B. Mishell and S.M. Shiigi, W.H. Freeman and Co., San Francisco, p. 103). Briefly, the SRBC were washed 4 times in cold saline, mixed with 2 mg of (CA)₂₅:(TG)₂₅ coupled to D-EK in 0.35M mannitol, 0.01 M NaCl containing 10 mg of carbodiimide and incubated for 30 minutes at 4°C. The coated SRBC were washed twice with cold Balanced Salt Solution and resuspended to 10% (v/v).

Plaque assay: The number of anti-PN plaque forming cells (pfc) was determined using the Cunningham technique (Marbrook, J., "Liquid Matrix (Slide Method)", in Selected Methods in Cellular Immunology, (1980), Eds. B.B. Mishell and S.M. Shiigi, W.H. Freeman and Co., San Francisco, p. 86.) The number of IgG pfc were determined by elimination of IgM plaques using rabbit and anti-mouse IgG as described by Henry ("Estimation of IgG responses by Elimination of IgM Plaques" in Selected Methods in Cellular Immunology, (1980), Eds. B.B. Mishell and S.M. Shiigi, W.H. Freeman and Co., San Francisco, p. 91). Briefly, spleens were harvested and single cell suspensions made in balanced salt solution (BSS). Guinea

-102-

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pig serum was added to polynucleotide coated SRBC to give
a final dilution of 1:9 guinea pig serum, and enough
rabbit anti-mouse IgG was added to give a final dilution
5 of 1:100 rabbit anti-mouse IgG. Equal volumes of the
SRBC mixture and diluted spleen cells were mixed in
microtiter wells and transferred to Cunningham chambers.
Each spleen was tested individually and in triplicate.
The edges of the chambers were sealed with paraffin and
10 the chambers were incubated at 37°C for 1 hour. The
number of plaques were enumerated by viewing the chambers
under an inverted microscope.

Results

15 Mice were primed with PN-KLH precipitated on alum
with pertussis as an adjuvant (A&P) and seven weeks later
divided into groups of 3 mice each. The mice were
treated, i.p., with doubling dilutions of PN-DABA-PEG,
Conjugate 3-II five days later all of the mice, including
20 the control, were boosted with 50 µg of PN-KLH, in
saline, i.p. Four days later, the spleens were harvested
and the number of IgG pfc determined. As shown in Table
2, all doses of Conjugate 3-II tested showed a
significant reduction in the number of pfc as compared to
25 the control group.

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-103-

Table 2Tolerogenic Activity of Conjugate 3-II (PN-DABA-PEG)

5	Dose ($\mu\text{g}/\text{mouse}$)	pfc/ 10^6 spleen cells	% Reduction
		Mean (S.D.)	Mean
	None	12865 (2846)	
	62.5	2868 (6809)	77.7
10	125	3331 (939)	74.1
	250	3044 (1929)	76.3
	500	1809 (759)	85.9
	1000	2814 (554)	78.1

15

Example 7Preparation and Testing of Conjugate 20-II

Conjugation of 5' Modified (CA)₁₀ to Valency Platform
Molecule 20 - Preparation of Single-Stranded Conjugate
20-I

20

969 μL (789 mg, 3.89 mmol) of tri-n-butylphosphine was added to a solution of 918 mg (0.14 mmol) of 5'-modified (CA)₁₀ in 30 mL of H₂O under argon atmosphere. The mixture was stirred for 1 hour and then 2.4 mL of a 3M NaCl solution was added followed by 42 mL of isopropanol which had been sparged with helium to remove oxygen. The mixture was placed in a freezer at -20°C for 1 hour and then centrifuged at 3000 rpm for 30 minutes. The supernatant was removed and the oily residue was dissolved in 15.5 mL of helium sparged H₂O. 1.24 mL of 3M NaCl and 21.7 mL of helium sparged isopropanol was added to the mixture. The resulting mixture was then placed in a freezer at -20°C for 1 hour

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-104-

and centrifuged at 3000 rpm for 20 minutes. The oily
pellet was dried under vacuum for 18 hours to yield a
solid. The solid was dissolved in 6 mL of helium sparged
H₂O to give a total volume of 6.4 mL. The amount of DNA
was 863 mg as determined by UV absorbance at 260 nm
(0.033 mg per unit of absorbance in pH 7.5 phosphate
buffered saline). The solution was transferred to a 50
mL three-neck flask under argon. One neck of the flask
had an argon gas inlet while the other two necks were
stoppered. The total volume was adjusted to 7.7 mL with
H₂O and 0.87 mL of helium sparged 1M sodium phosphate
buffer, pH 7.8, and 0.97 mL of MeOH. 1.9 mL (33.63 mg,
0.025 mmol) of a 17.7 mg/mL solution of compound 20 in
MeOH was added to the mixture. The resulting mixture was
stirred under argon for 20 hours and then diluted to 100
mL with a solution comprising 0.1 M NaCl, 0.05 M sodium
phosphate, pH 7.5, and 10% MeOH. Purification was
accomplished by chromatography on Fractogel®
(equilibration: 0.1 M NaCl, 0.05 M sodium phosphate, pH
7.5, 10% MeOH: elution gradient 0.5 M NaCl, 0.05 M
sodium phosphate, pH 7.5, 10% MeOH to 0.8 NaCl, 0.05 M
sodium phosphate, pH 7.5, 10% MeOH). Fractions
containing pure conjugate 20-I as evidenced by HPLC and
polyacrylamide gel electrophoresis were collected in 232
mL of eluent. The product and salts were precipitated by
adding an equal volume of isopropanol and placing same in
a freezer at -20°C for 1 hour. Dialysis against H₂O (2 x
100 vol) gave 335 mg of conjugate 20-I (32 mL of 10.47
mg/mL, 0.033 mg/absorbance unit at 260 nm).

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-105-

Annealing of Conjugate 20-I with (TG)₁₀ to Form Double-Stranded Conjugate 20-II

150 mg (14.33 mL of 10.47 mg/mL based on 0.033
mg/absorbance unit at 260 nm) of conjugate 20-I and 157.5
5 mg (1.50 mL of 104.6 mg/mL based on 0.033 mg/absorbance
unit at 260 nm) of (TG)₁₀ were placed into a 50 mL
polypropylene centrifuge tube. The concentration was
adjusted to 15 mg/mL by adding 2.0 mL of pH 7.2 10X PBS
and 2.17 mL of H₂O. The mixture was placed in a 90°C
10 water bath and allowed to cool to room temperature over
1.5 hours. The concentration was determined to be 17.7
mg/mL by absorbance at 260 nm (0.050 mg/absorbance unit);
transition melt temperature 67.5°C; hyperchromicity 27%;
osmolality 346; pH 7.2. For final formulation of
15 conjugate 20-II, the solution was diluted to a final
concentration of 12.7 mg/mL and an osmolality of 299 by
adding 7.23 mL of pH 7.2 ½ X PBS and filtering through a
0.22 µ filter.

20 Alternative Conjugation of 5'-Modified (CA)₁₀₋₂₀
Preparation of Single Stranded Conjugate 20-I

10 equivalents of tri-n-butylphosphine are
added to a 10 mg/mL solution of 5'-modified (CA)₁₀ in He
sparged with 100 mM pH 5 sodium acetate. The mixture is
25 stirred for 1 hour and then precipitated with 1.4 volumes
of isopropyl alcohol (IPA). The mixture is placed in the
freezer at -20°C for 1 hour and centrifuged at 3000 rpm
for 20 minutes. The supernatant is removed and the
pellet is dissolved to 10 mg/mL in He sparged IPA. The
30 mixture is placed in the freezer at -20°C for 1 hour and
centrifuged at 3000 rpm for 20 minutes. The pellet is
dried under vacuum for 18 hours to give a solid. A 50
mg/mL solution of the solid is prepared in He sparged 100
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-106-

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mM pH 10 sodium borate buffer. 0.25 equivalents of compound 20 as a 40 mg/mL solution in 9/1 MeOH/H₂O is added to the mixture. The mixture is stirred at room temperature for 3-20 hours and diluted (0.1 M NaCl, 0.05 sodium phosphate, pH 7.5, 10% MeOH). Purification is accomplished by chromatography on Factogel (equilibration; 0.1 M NaCl, 0.05 M sodium phosphate, pH 7.5, 10% MeOH: elution gradient; 0.5 M NaCl, 0.05 M sodium phosphate, pH 7.5, 10% MeOH to 0.8 M NaCl, 0.05 M sodium phosphate, pH 7.5, 10% MeOH). Fractions containing pure 20-I, as evidenced by HPLC and polyacrylamide gel electrophoresis, were collected. The product and salts are precipitated by adding an equal volume of IPA and standing in the freezer at -20°C for 1 hour. Dialysis against H₂O (2 X 10 vol) give 20-I.

Alternative Annealing of 20-I with (TG)₁₀₋₂₀ to Form Double Stranded Conjugate 20-II

The methodology is essentially the same as that described above except that annealing is done at 70°C instead of 90°C.

Second Alternative Conjugation of 5'-Modified (CA)₁₀₋₂₀ Preparation of Single Stranded Conjugate 20-I

4.8 mL of tri-n-butylphosphine was added to a solution of 7.75 g of 5'-modified (CA)₁₀ in 104 mL of Ar sparged 100 mM pH 5 sodium acetate under N₂. The mixture was stirred for 1 hour and then precipitated with 232.5 mL of IPA. The mixture was placed in a freezer for -20°C for 1.5 hours, centrifuged at 3000 rpm for 20 minutes and then frozen at -20°C for 24 hours. The supernatant was removed and the pellet was dissolved in 170 mL He sparged 0.3 M NaCl solution. The mixture was again precipitated

-107-

with 232 mL of Ar sparged IPA. The mixture was then placed in a freezer at -20°C for 2 hours, centrifuged at 3000 rpm for 20 minutes and then from at -20°C for 11 hours. The supernatant was decanted and the pellet was dried under vacuum for 12 hours to give a solid. A solution of the solid was prepared in 110 mL of Ar sparged 100 mM pH 10 sodium borate buffer. 406 mg of compound 20 as a solution in 4.4 mL of 9/1 MeOH/H₂O was added to the mixture. The mixture was stirred at room temperature for 2 hours. The product mixture contained 62% of 20-I by high-pressure ion chromatography, Waters Gen Pak Fax column (100 X 4 mm), 60°C, linear gradient from 65%A/35%B to 18%A/82%B; A=0.05 M NaH₂PO₄, pH 7.5, 1 mM EDTA, 10% MeOH (v/v); B=0.05 M NaH₂PO₄, pH 7.5, 1 M NaCl, 1 mM EDTA, 10% MeOH (v/v), eluting at 19.5 minutes.

Testing of Conjugate 20-II and Nonconjugated Controls

C57BL/6 mice were immunized with PN-KLH and A&P. After three weeks, groups of 5 mice/group were treated with either different doses of Conjugate 20-II or 4.5 nM HAD-AHAB-TEG (linker, HAD, attached to derivatized valency platform molecule, AHAB-TEG, see Figure 7), or 18 nM (4 X 4.5) (CA)₁₀:(TG)₁₀, or a mixture of 4.5 nM HAD-AHAB-TEG plus 18 nM (CA)₁₀:(TG)₁₀, i.p.; and one group was not treated. The groups were given booster injections and the sera were collected and assayed as described in Example 6. The percent reduction of the anti-PN response is shown in Figure 4. The anti-KLH responses of these mice was normal and were not significantly different than those shown in Figure 2. The results clearly show that the anti-PN response was not affected by (i) the valency platform molecule alone, (ii) the PN alone, or (iii) a mixture of the two. The PN

-108-

must be coupled to the nonimmunogenic valency platform molecule in order to induce tolerance.

5 Conjugate 20-II Causes a Reduction in the Number of PN-specific Antibody Producing Cells

C57Bl/6 mice were immunized with PN-KLH, A&P. After three weeks, groups of 3 mice/group were treated with different doses of Conjugate 20-II, i.p; one group was not treated. After five days, all of the mice were
10 given a booster injection of PN-KLH in saline, i.p., and then 4 days later their spleens were harvested and assayed for the number of PN-specific, IgG-producing cells using the hemolytic plaque assay. The results, shown in Table 3, clearly show that this conjugate
15 reduced the number of PN-specific IgG-producing cells.

TABLE 3
REDUCTION IN THE NUMBER OF pfc BY
Conjugate 20-II

Group#	Dose <u>µg/mouse</u>	PN-specific pfc per 10 ⁶ spleen cells (Mean & S.E.)		<u>% Reduction</u>
1	None	5562	(2570)	
25 2	274	982	(1871)	82.3
3	91	1867	(1335)	66.4
4	30	2247	(1606)	59.6
5	10	6109	(2545)	0
6	3	4045	(1411)	27.3
30 7	1	4578	(2475)	17.7
8	0.4	5930	(897)	0

-109-

Example 8

Testing of Conjugates as Tolerogens

Testing of Conjugate 17-II as a Tolerogen

5 C57BL/6 mice were immunized with PN-KLH, A&P. Three weeks later groups of 5 mice/group were treated with different doses of Conjugate 17-II intraperitoneally, (i.p.), and one group was not treated. 10 Five days later all of the mice were given a booster injection of PN-KLH, in saline, i.p., and 7 days later the mice were bled. The sera were analyzed for anti-PN antibody by the Farr assay at a PN concentration of 10^{-4} M. The percentage reduction of the anti-PN response is shown 15 in Figure 1. The sera were also analyzed for anti-KLH antibodies using an ELISA assay. The results, expressed as the percentage of anti-KLH compared to a standard pool of anti-KLH sera, are shown in Figure 2. The data in Figure 1 show that this conjugate reduces the anti-PN 20 response. The anti-KLH (platform molecule) response in all of the mice is normal (see Figure 2).

Testing of Various of the 11 Series of Conjugates as Tolerogens

25 Groups of three C57BL/6 mice/group were immunized with PN-KLH, A&P. After three weeks, two groups were treated with 3 different doses of either Conjugate 11-IV, Conjugate 11-II, Conjugate 11-VI or Conjugate 11-VIII, i.p., one group was not treated. These 30 conjugates are described in Figures 6A-B and were prepared according to the methodology described above in Example 7. Five days later all of the mice were given a booster injection of PN-KLH, in saline, i.p., and 7 days 35 later the mice were bled. The sera were analyzed for

-110-

anti-PN antibody by the Farr assay at a PN concentration of 10^{-6} M. The results showing the percentage reduction in the anti-PN response are presented in Figure 3. The anti-KLH responses in these mice were not significantly different than the responses shown in Figure 2. All four conjugates significantly reduced the anti-PN response at all doses tested.

Conjugate 11-II Causes a Reduction in the Number of PN-specific Antibody Producing Cells

C57Bl/6 mice were immunized with PN-KLH, A&P. After three weeks, groups of 3 mice/group were treated with different doses of Conjugate 11-II, i.p., one group was not treated. Five days later, all of the mice were given booster injections of PN-KLH in saline, i.p.; and 4 days later their spleens were harvested and assayed for the number of PN-specific, IgG-producing cells using the hemolytic plaque assay. The results of this experiment with different doses of Conjugate 11-II are shown in Table 4. These results clearly show that this conjugate reduced the number of PN-specific IgG-producing and that the reduction in antibody titer was not due to the clearance of serum antibody bound to conjugate.

-111-

TABLE 4
REDUCTION IN THE NUMBER OF pfc BY
Conjugate 11-II

5	Group#	<u>μg/mouse</u>	PN-specific		pfc per 10 ⁶		spleen cells		% Reduction	
			(Mean & S.E.)		(SD)					
10	1	None	10845	(1308)						
	2	263	3613	(547)	66.23	(8.6)				
	3	87	3462	(1041)	64.98	(17)				
	4	29	7354	(1504)	29.5	(23.8)				
	5	9	6845	(2031)	30.9	(32.2)				
	6	3	7982	(223)	26.8	(3.52)				
	7	1	6043	(545)	44.5	(7)				
	8	0.4	9343	(1251)	13	(19.8)				
15										
20										
25										
30										
35										

-112-

Example 9

Preparation of HADpS-(CA)₁₀ - Conjugate 20-IV

5 A modified polynucleotide with a
phosphorothioate joining the linker to the 5' end was
prepared. Synthesis of the twentymer, (CA)₁₀, and the
addition of the HAD linker to the polynucleotide was
carried out according to the methodology of Example 5
except for the following. In the final oxidation step,
10 the iodine solution was replaced with a 0.05 M solution
of 3H-1,2-benzodithiole-3-one 1,1 dioxide (Glen Research,
Sterling, VA) in acetonitrile. Sulfurization was carried
out according to the manufacturer's instruction. Ammonia
treatment and purification were carried out as in Example
15 5. Conjugation of the polynucleotide to the AHAB-TEG
valency platform were carried out according to the
methodology of Example 5.

Testing of Conjugate 20-IV as a Tolerogen

20 Because the 5' phosphate on the PN may be
susceptible to enzymatic degradation, one of the oxygen
molecules on the terminal phosphate was replaced with
sulfur -- thus the name HAD_pS. C57BL/6 mice were
immunized with PN-KLH, A&P. After three weeks, groups of
25 5 mice/group were treated with different doses of
Conjugate 20-IV, i.p.; one group was not treated. The
groups were given booster injections and the sera were
collected and assayed as described above. The results
showing the percentage reduction in the anti-PN response
30 are shown in Figure 5. The anti-KLH responses of these
mice (data not shown) were normal and were not
significantly different that those shown in Figure 2.
These results show that this conjugate significantly
35 reduced the anti-PN response.

-113-

Conjugate 20-IV Causes a Reduction in the Number of PN-specific Antibody Producing Cells

C57Bl/6 mice were immunized with PN-KLH, A&P. After three weeks, groups of 3 mice/group were treated with different doses of Conjugate 20-IV, i.p.; one group was not treated. After five days, all of the mice were given a booster injection of PN-KLH in saline, i.p., and 4 days later their spleens were harvested and assayed for the number of PN-specific, IgG-producing cells using the hemolytic plaque assay. The results, shown in Table 5, show that this conjugate reduced the number of PN-specific IgG-producing cells.

TABLE 5
REDUCTION IN THE NUMBER OF pfc BY
Conjugate 20-IV

	<u>Group#</u>	<u>Dose</u> <u>μg/mouse</u>	<u>PN-specific</u> <u>pfc per 10⁶</u> <u>spleen cells</u> <u>(Mean & S.E.)</u>	<u>% Reduction</u>
20	1	None	5889.4 (3444)	
	2	274	3413 (1604)	42
	3	91	222 (752)	96.2
	4	30	1492 (2269)	74.7
	5	10	5421 (832)	8
25	6	3	5077 (1946)	13.9
	7	1	7023 (679)	0
	8	0.4	4159 (2688)	29

-114-

EXAMPLE 10

TREATMENT OF BXS_B MICE WITH LJP 394, CONJUGATE 20-II

Mice Treatment Protocol

Six to 9 week old male BXS_B mice (Jackson Laboratory, Bar Harbor, Me) were housed at the La Jolla Pharmaceutical facility. Food and water were provided ad libitum. Animals were rested one week prior to use. Initial blood samples and weights were obtained prior to the first conjugate treatment. Conjugate treatment was initiated at 7 to 9 weeks of age and was administered intravenously twice weekly from day 59 to day 150. Animals were bled periodically and their anti-DNA antibody titers were determined.

Assay for IgG Anti-DNA Antibody Production

A serum sample taken from each mouse was assessed for the presence of anti-DNA antibody by ELISA. Falcon Probind 96 well microtitration assay plates (Becton Dickerson, Oxnard, CA) were coated with 100 μ L/well of (PN)₃₀-D-EK (a co-polymer of D-glutamic acid and D-lysine) at a concentration of 50 μ g/mL overnight at 4°C. The plates were washed twice with PBS without calcium and magnesium and 0.05% Tween 20 (wash buffer) using a M96V plate washer (ICN Biomedical, Inc., Irvine, CA). Plates were blocked for 1 hour at room temperature in PBS containing 1% gelatin (Norland Products, Inc., New Brunswick, NJ) and 0.05% Tween 20. Plates were washed twice with wash buffer before the addition of serum samples or standards. Serum samples and standards were prepared in a diluent containing PBS with 1% gelatin, 0.05% Tween 20 and 10% goat serum. Plates were incubated with serum samples for 60 to 90 minutes at 37°C and then

-115-

the wells were washed four times with wash buffer.
Biotinylated goat anti-mouse IgG (Sigma Chemical Co., St.
Louis, MO) was diluted 1/1000 in blocking solution
5 containing 10% goat serum. The plates were incubated for
1 hour at 37°C and washed four times. The substrate, OPD
(Sigma Chemical Co., St. Louis, MO), was added. The
plates were incubated in the dark until the highest
reading of the highest standard was approximately 1 OD
10 unit by an ELISA plate reader at OD 450 nm (Bio-Tek
Instruments, Winooski, VT). The reaction was stopped
with 50 µL of 3M HCl and the plates were read at 490 nm.
The reference positive serum was included in each
microtitration plate and the positive wells from each
15 assay were within the sensitivity range of the reference
curve 95% of the time. In the later bleeds, some
positive samples exceeded the reference curve. However
the most dilute mouse serum sample was within the range
of the reference curve. No significant binding was
20 observed by normal control negative serum.

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-116-

EXAMPLE 11

PREPARATION OF MELITTIN PEPTIDES AND CONJUGATE

5 The melittin molecule, composed of 26 amino acids, is one of the major components of bee venom. One third of the bee venom sensitive individuals have melittin specific antibodies. Melittin is highly immunogenic in some mouse strains (Balb/c, CAF1). The majority (>80%) of melittin specific antibodies in the responder mouse strains bind a B cell epitope which is the c-terminal heptapeptide of melittin.

Melittin

15 H₂N-Gly-Ile-Gly-Ala-Val-Leu-Lys-Val-Leu-Thr-Thr-Gly-Leu-Pro-Ala-Leu-Ile-Ser-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-CONH₂ (SEQ. ID.: 1).

Melittin Peptides for T cell Stimulation

Melittin Peptide #1.

20 Ile-Lys-Arg-Lys-Arg-Gln-Gln-Gly ("7 mer") (SEQ. ID NO.: 2).

Melittin Peptide #2.

Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-Gly ("8 mer") (SEQ. ID NO.: 3).

25 Melittin Peptide #3.

Ser-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-Gly ("9 mer") (SEQ ID NO.: 4).

Melittin Peptide # 4.

30 Ile-Ser-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-Gly ("10 mer") (SEQ. ID NO.: 5).

Melittin Peptide #5.

35 Cys-Ile-Ser-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-Gly ("11 mer") (SEQ. ID NO.: 6).

-117-

Peptide Synthesis

Melittin peptides were synthesized using standard Fmoc chemistry techniques on a glycine resin (Advanced ChemTech #SG5130 or equivalent (Advanced ChemTech, 2500
5 Seventh Street Road, Louisville, KY) using 2.3 M excess amino acid derivatives for each coupling step. Completion of the coupling was monitored with bromphenol blue and confirmed with ninhydrin.

Melittin Peptides Used in Conjugations

Melittin Peptide #6.

H₂N-Cys-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-Gly-CO₂H (SEQ. ID NO.: 7).

Melittin Peptide #7.

15 H₂N-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-Lys-Cys-Gly-CO₂H (SEQ. ID NO.: 8).

~~**Melittin Peptide #8.**~~

20 ~~H₂N-Cys-Ile-Ser-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln-Gly-CO₂H (SEQ. ID NO.: 9).~~

Melittin Peptide #9.

(H₂N-Trp-Ile-Lys-Arg-Lys-Arg-Gln-Gln)₂-Lys-Cys-Gly-CO₂H (SEQ. ID NO.: 10).

25 A cysteine was added as required for coupling certain peptides via a thioether bond to the valency platform molecule. Peptides were purified by reversed phase HPLC following synthesis and lyophilized to dryness. The appropriate amount of peptide was then
30 weighed out for each conjugation.

-118-

Reduction of Preformed Disulfide Bonds:
(Tributylphosphine Method)

5 All buffers were sparged with helium. The peptide was dissolved in a minimal volume (approximately 10 to 20 mg/mL) of 0.05 M NaHCO₃ (pH 8.25). A 1 mL solution of 0.7 M tributylphosphine (TBP; MW = 202.32 g/mole; d = 0.812 g/mL) was prepared by adding 174.4 µL of TBP to 825.6 µL of isopropanol (iPrOH). Then, 1:1 equivalents of TBP were added to the peptide solution prepared as described above, mixed well, and allowed to react for 30 minutes to 1 hour with occasional mixing to keep TBP dissolved and/or dispersed in the solution. Complete reduction was confirmed by HPLC.

15 Conjugation of Peptides to Valency Platform Molecule #3 or #60:

All buffers were sparged with helium. The polyethylene glycol (PEG) derivative #3 or #60 was dissolved in a minimal volume (approximately 20 mg/mL) of 0.05 M NaHCO₃ (pH 8.25). Approximately 3 equivalents of peptide were used per iodacetyl group on the PEG derivative. For para-aminobenzoic acid (PABA)-PEG; 2 iodacetyl groups; MW = approximately 4100 g/mole; 6 equivalents of peptide were used for each equivalent of PABA-PEG. For diaminobenzoic acid (DABA)-PEG; 4 iodacetyl groups; MW = approximately 4300 g/mole; 12 equivalents of peptide were used for each equivalent of DABA-PEG. The PEG solution was added to the reduced peptide solution and allowed to react for at least one hour in the dark. The peptide conjugate was purified by preparative HPLC. Before pooling and lyophilization, fractions were checked by electrophoresis using a 15% tricine gel.

Table 2
Conjugates of Melittin Peptides and PEG

Conjugate number	Valence platform	Peptide conjugated	# B cell epitopes /molecule	Conjugation terminus	T cell activation by peptide or conjugate ¹
1	5	6	2	N	no (pep)
2	3	6	4	N	no (pep/conj)
3	3	7	4	C	nd
4	3	5	4	N	yes (pep)
5	3	8 ²	8 ²	C	nd

¹ Stimulation of uptake of [³H] thymidine by cultured T cell from melittin-immunized mice; nd = not determined; pep = peptide tested; conj = peptide-PEG conjugate tested.

² 4 copies of a branched peptide, containing two identical branches each; each branch comprising a B cell epitope

-120-

Murine Lymph Node Proliferation Assays.

Female Balb/c mice (6-8 weeks old; Jackson Laboratory, Bar Harbor, Maine) were obtained and housed at the La Jolla Pharmaceutical animal facility according to National Institutes of Health guidelines. Food and water was provided ad libitum. Balb/c mice were immunized in each hind footpad with 50 μ g of melittin molecule in Complete Freund's Adjuvant (CFA) (Sigma Chemical Co., St. Louis, MO). Popliteal lymph nodes were harvested aseptically seven days later. Lymph nodes were gently dissociated by teasing the cells through a 50 mesh sieve screen. The single cell suspension was washed in RPMI-1640 (Irvine Scientific, Irvine CA) containing glutamine, penicillin and streptomycin. 5×10^5 cells in RPMI medium supplemented with 10% fetal bovine serum (FCS) in quadruplicate wells of round bottom 96-well Corning microtitration plates were cultured with melittin or a melittin peptide at 10, 1.0 or 0.1 μ g/mL. Cells in the positive control wells were cultured with murine interleukin 2 (IL-2) at 100 or 50 U/mL, PHA (phytohemagglutinin) at 1 μ g/mL. The negative control wells contained lymph node cells in RPM-1640 and 10% FCS. The cells were cultured for 4 days in a 37°C incubator with 5% CO₂. Each well was pulsed with 1 μ Ci of [³H]thymidine (ICN Biochemicals, Costa Mesa, CA) for an additional 18 hours. Cells were harvested onto a glass fiber filter mat using a semiautomatic cell harvester (Scatron, Sterling, VA). Incorporation of [³H]thymidine was determined by liquid scintillation. The results were expressed as average counts per minute.

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-121-

In vivo Protocols

Balb/c mice were primed intraperitoneally (i.p.) with 4 μ g of melittin in CFA. One month later the potential tolerogen or formulation buffer was administered i.p. Three days later all mice received an i.p. injection of 4 μ g of melittin in Incomplete Freund's Adjuvant (ICF) (Sigma Chemical Co., St. Louis, MO). 100 to 200 μ L of blood was collected from the retro-orbital venous plexus 10 days later. Serum samples were assayed for anti-peptide or anti-melittin IgG antibodies.

Assay for IgG Anti-Melittin or Total Anti-Melittin Antibodies

An individual mouse's serum sample was assessed serially for the presence of anti-melittin antibodies by ELISA. Falcon Probind 96-well microtitration plates were precoated with 10 μ g/mL melittin or melittin peptide in phosphate buffered saline (PBS), pH 7.2, overnight at 4°. The plates were washed twice with a wash solution containing PBS, 0.02% Tween-20, and 1% gelatin (Norland Products Inc., New Brunswick, NJ). Plates were blocked with 200 μ L PBS containing 5% gelatin for 1 hour at 37°. Serum samples were prepared in a diluent of PBS containing 5% gelatin. Samples were tested at dilutions of 1:100 to 1:1000. After 1 hour of incubation at 37°C, the plates were washed four times. ExtraAvidin peroxidase (Sigma Chemical Co., St. Louis, MO) was diluted 1:1000 in PBS containing 5% gelatin. The plates were incubated 30 minutes at 37°C and then washed five times. Wells were developed with o-phenylenediamine (OPD) (Sigma Chemical Co., St. Louis, MO) in the dark for 15-30 minutes, the reaction was stopped with 3 M HCl.

-122-

The optical density (OD) was determined at 450 nm on a microplate reader (Bio-tek Instruments, Winooski, VT).

5 Antibody Forming Cell Assay

Cellulose microtitration plates (Millipore Co., Bedford, MA) were prepared as indicated above for the IgG antibody (ELISA) assay. However, at the point in the assay where the serum samples were added to the wells, splenic cells (5×10^5 /well) were added instead of serum, and incubated overnight. The remainder of the ELISA assay was performed as indicated above.

15 T Cell Epitopes

T Cells from mice primed with melittin showed T cell proliferation in response to the whole melittin molecule and to C-terminal melittin peptides 3, 4, and 5 (Figure 8). However, C-terminal peptides 1 and 2 induced no significant T cell proliferation. Melittin peptides 2 and 5 were conjugated to PEG. Like melittin peptide 2, the PEG conjugate of melittin peptide 2 (Conjugate 2) also did not induce significant T cell proliferation.

25 Studies Using Melittin Conjugated Peptides to Tolerize Mice Primed and Boosted with Melittin

Mice treated with Conjugate 2 (10 mg/kg, 200 μ g/mouse), had significantly lower levels of anti-melittin peptide 2 antibodies (Figure 9) and also lower levels of anti-melittin antibodies (Figure 10) as compared to the control Balb/c mice treated with formulation buffer. Spleen cells from mice treated with buffer control or Conjugate 2 were assayed for the ability of antibody-forming cells to produce anti-melittin or anti-melittin peptide 2 antibodies as

-123-

measured in a soluble ELISA assay. As shown in Figure 11, the levels of anti-melittin peptide 2 antibody forming cells in the Conjugate 2 treatment group were significantly lower than in the control group which was administered formulation buffer. Mice treated with Conjugate 4, a conjugate of peptide 5 which contains a T cell epitope, failed to reduce the titer of antibodies to peptide 5 in treated mice. Thus, the conjugate containing a T cell epitope was not a tolerogen (Figure 12). In fact, rather than reduce the response, the levels of anti-peptide antibody may have increased slightly.

EXAMPLE 12

Additional Studies Using Melittin Peptide Conjugates to Tolerize Mice Primed and Boosted with Melittin

Female C57BL/6 mice, ages 5 to 8 weeks were purchased from The Jackson Laboratory, Bar Harbor, ME. Animals were maintained and treated accordingly to National Institutes of Health guidelines.

Immunization Protocol

Mice were primed by an i.p. injection containing 5 µg of melittin precipitated on alum and 2 x 10⁹ B. pertussis (Michigan Department of Public Health, Lansing, MI) as an adjuvant. The mice were boosted with 5 µg of melittin, i.p., in PBS.

pfc Assay

Sheep Red Blood Cells (SRBC) (Colorado Serum Co., Denver, Colorado) were conjugated with melittin-peptide 2 using carbodiimide. Fresh SRBC (less than 2 weeks old) were washed four times with cold saline and one time with

-124-

mannitol (0.35 M mannitol, 0.01 M NaCl). The SRBC were
suspended in mannitol to a concentration of 10% (v/v).
100 μ L of mannitol containing 30 μ g of melittin peptide
#3 were added to 1 mL aliquots of 10% SRBC which were
5 then incubated on ice for 10 minutes. 100 μ L of a 100
mg/mL solution of 1-ethyl-3
(3-dimethylaminopropyl)-carbodiimide HCl (EDCI) was then
added and incubated on ice for 30 minutes. The SRBC were
10 washed twice with Balanced Salt Solution (BSS) (Irvine
Scientific Co, Irvine, CA) and resuspended to 10% (v/v).
Lyophilized guinea pig complement (GIBCO, New York, NY)
was reconstituted with BSS and then diluted 1:3 with BSS.
One mL of the diluted guinea pig complement was added to
15 3 mL of conjugated SRBC. Rabbit anti-mouse IgG was added
to give a final dilution of 1:100 of the rabbit
antiserum. This concentration was predetermined to
inhibit all IgM pfc while enhancing the maximum number of
IgG pfc. An equal volume of this complement/anti-mouse
20 IgG/SRBC suspension was mixed with a cell suspension of
mouse spleen cells taken from a single mouse. 50 μ L of
each mixture was transferred to the chambers of a
Cunningham slide (three chambers per slide). The edges
were then sealed with paraffin and incubated at 37°C for
25 one hour. The number of plaques per chamber was counted
with the aid of a dissecting microscope. Each spleen
suspension was also assayed using non-conjugated SRBC as
a control. The number of viable cells, in each spleen
cell suspension, was determined. The number of pfc per
30 10^6 spleen cells was determined for each chamber and the
mean of the triplicates calculated. The number of pfc
for non-conjugated SRBC was subtracted from the number of
pfc for conjugated SRBC to determine the number of
35 peptide-specific pfc.

-125-

Determining The Optimal Time to Measure pfc

Mice were primed with melittin. Groups (3 mice per group) of primed mice were boosted with melittin on days 2, 4, 6, and 8. On day 10 the mice were sacrificed and their spleens harvested. Cell suspensions were prepared and assayed for the number of peptide specific pfc determined. The optimal number of pfc was obtained 6 days after boosting with melittin.

The Orientation of The Peptide on The PEG Conjugate Does Not Affect The Conjugate's Ability to Induce Tolerance

Two different tolerogens were constructed to determine if the orientation of the peptide on the PEG conjugate affects its ability to induce tolerance. The peptide was covalently bound to valency platform molecule 3 through its C-terminal end to make melittin conjugate 3. Groups (3/group) of mice primed with melittin were treated, i.p., with conjugates or with saline. Five days later all of the mice, including the non-treated control group, were boosted with 5 μ p of melittin. Six days later the mice were sacrificed, their spleens were harvested and the number of peptide specific pfc determined. As illustrated in Table 6, both orientations were effective in reducing the number of peptide-specific pfc/ 10^6 spleen cells in mice primed and boosted with the parent protein Melittin.

-126-

Table 7
Orientation of the peptide on the PEG conjugate does not
affect the conjugates' ability to induce tolerance

5	Melittin Conjugate#	$\mu\text{g}/\text{mouse}$	Peptide specific pfc per 10^6 spleen cells (Mean and S.D.)	% Reduction
	3	1000 μg	386 (85)	86.8%
	"	500 μg	489 (one mouse)	83.3%
	"	250 μg	957 (298)	67.3%
10	2	1000 μg	546 (160)	81.3%
	"	500 μg	866.6 (235)	70.4%
	"	250 μg	1280 (one mouse)	56.2%
	None	None	2924 (164)	- -

15 The Number of Peptides per PEG Conjugate Does Affect The
Conjugate's Ability to Induce Tolerance

Three different conjugates, each with a
different number of peptides per PEG conjugate, were
constructed to determine if the ratio of peptides to PEG
molecule was important. Conjugate 1 had only two
20 peptides per PEG conjugate. Another had four peptides
per PEG conjugate (Conjugate 2). The third had eight
peptides per PEG conjugate (Conjugate 5). Groups
(3/group) of mice primed with melittin were treated,
25 i.p., with the different conjugates or with saline. Five
days later all of the mice, including the non-treated
control group, were boosted with 5 μg of melittin. Six
days later, the mice were sacrificed, their spleens were
harvested and the number of peptide-specific pfc
30 determined. As shown in Table 8, Conjugate 1, containing
two peptides per PEG molecule, was ineffective in
reducing the number of peptide-specific pfc/ 10^6 spleen
cells in mice primed and boosted with the parent protein
35 melittin. The results show that both melittin conjugates

-127-

2 and 5 were effective as tolerogens; however, conjugate
5, which contained 8 peptides, was effective at a lower
dose than conjugate 2 which contained four peptides per
valency platform molecule.

Table 8

The number of peptides per PEG conjugate does
affect the conjugates' ability to induce tolerance

Treatment Molecule	Dose μg/mouse (nMoles)	Peptide specific indirect IgG	
		pfc(SD)	% Reduction
No treatment		1159 (280)	std
Conjugate 1	1000 (217)	1290(98)	-11%
	250 (54)	1350(206)	-16%
Conjugate 2	500(80)	585(125)	49.5%
	250(40)	1001(176)	14%
Conjugate 5	500(53)	630(325)	45.6%
	250(26.5)	443(105)	61.8%
	125(13.25)	583(69)	49.7%

Modifications of the above-described modes for
carrying out the invention that are obvious to those of
skill in the fields of polynucleotide chemistry,
conjugation chemistry, immunology and related fields are
intended to be within the scope of the following claims.